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MARINE PRODUCTS OF COMMERCE

Their Acquisition, Handling, Biological Aspects and the Science and Technology of Their Preparation and Preservation

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Preface.

This book is designed for both the scientific and the practical man. It attempts to give the chemist and biologist a general survey of the fishery industries, pointing out their relative importance, indicating their location, and describing the methods in common use. There has been no attempt to consider all the methods of the fisheries; if this were attempted, a lengthy treatise such as G. Brown Goode's "Fisheries and fishery industries of the United States" would result.

By reading this book, the practical man may learn how chemistry and biology are correlated with the fishery industries. Simple language is used throughout. But few technical terms are included and care is taken to define those terms which may not be familiar to the layman.

The author hopes that this book may fill the long felt need of the student of industrial biology, for a concise treatise on the fishery industries. These industries have been considered from a scientific viewpoint and, while it is impossible to go into great detail in describing the applications of chemistry, physics, and biology in the preparation and preservation of marine products, the applications are outlined and references to the original literature are given which should serve as a guide for study.

In all cases, special consideration is given to American methods and processes. Obviously, it is impossible to treat of the technology of the marine products industries in all parts of the world; however, especially important foreign industries are described.

A special effort is made to describe carefully the manufacture and refining of solar sea salt. It is hoped that the information presented will be of value not only to the student of industrial chemistry and the marine industries but also to the salt manufacturer.

It is hoped that the book may call attention to the great need for chemical and biological research to solve the numerous problems of the fishery industries. Several of these problems are brought to the attention of the reader in the last chapter.

The author makes no claim for originality for any of the theories or facts presented within these covers. All available sources of information have been freely consulted and compared, and the most up-to-date information presented to the reader. The most valuable literature on the fisheries and fishery industries of the United States is the publications and files of the United States Bureau of Fisheries. In several instances the descriptions of methods given are merely summaries of the information obtained in the Bureau of Fisheries files.

The author and his collaborators have attempted to have all the facts presented accurate and up-to-date. Undoubtedly, unsuspected errors have crept in. We desire to be advised of any erroneous statements noted by the readers, so that, in case a second edition is advisable, it can be made more accurate.

The book completed, the more pleasant task remains to thank the many persons who have been so kind as to aid in its preparation. The author wishes to take this opportunity to thank his collaborators who have done so much to make this book a success. Without their assistance, the treatise could not have been made so comprehensive. I am greatly indebted to Mr. William A. Hamor, Assistant Director, Mellon Institute of Industrial Research, who first suggested that I write this treatise, and who has given many apt suggestions which have been most helpful. I owe much to my wife who has been untiring in her efforts to aid in the preparation of the manuscript.

Special mention should also be made of the following men who have read parts of the manuscript and have given many valuable suggestions for its correction and revision: Professor Francis H. Herrick, Western Reserve University; Dr. J. W. Turrentine and Dr. C. C. Spencer of the U. S. Bureau of Soils; Professor E. P. Churchill, University of South Dakota; Professor W. W. Browne, College of the City of New York; Professor E. V. McCollum, School of Hygiene and Public Health, Johns Hopkins University; Mr. Norman Hendrickson, National Canners Association; Mr. W. C. Schroeder, Mr. Harry Beard, and Mr. R. L. Greer of the Bureau of Fisheries; Mr. N. C. Phillips, Russia Cement Company; Mr. William T. Gamage, Gorton-Pew Fisheries Company; and Mr. John Palmer of Reedville, Virginia.

In addition to those named above, many other persons, too numerous to mention, aided in the work. Many have furnished photographs used in its illustration. Others have volunteered information and given suggestions.

The author hopes that the book will come up to the expectations of those who have so kindly aided in its preparation. If this is accomplished, I will feel that our efforts have been rewarded.

D. K. T.

Contents.

PAGE

CHAPTER 1.—ECONOMIC IMPORTANCE OF MARINE PRODUCTS . . 15

The Sea—Importance of Marine Products in History—Relative Importance of Marine Products—Variety of Products—Possibilities.

CHAPTER 2.—SALT FROM SEA WATER 24

The Composition of Sea Water—The Importance, Properties and Uses of Salt—Solar Salt—Importance and Location of Industry—The Oriental Leaching Method—The Oriental Solar Process—The European Solar Salt Process—The California Solar Salt Industry—Procedure at San Francisco Bay.

CHAPTER 3.—THE REFINING OF SEA SALT AND THE RECOVERY OF BY-PRODUCTS FROM BITTERN 47

The Necessity of Refining Sea Salt—American Processes of Refining Sea Salt—Principles and Methods—Refining by Rewashing—Refining by Recrystallization in Grainers—Recrystallization in Vacuum Pans—American Grades of Refined Sea Salt—The Recovery of By-Products from Bittern—The Importance of By-Products—Balard's Process—Merle and Péchiney's Modification—The California Process—Separation of the Salts by Freezing out the Sulphates—Fractional Crystallization to Recover Magnesium Sulphate, Potassium Chloride, and Magnesium Chloride.

CHAPTER 4.—IODINE AND POTASH FROM SEAWEEDS—EUROPEAN AND JAPANESE PROCESSES 70

Characteristics of Algæ—History of the Utilization of the Ash of Seaweed—Geographical Distribution of the European Industry—The British Seaweed-Burning Industry—Importance of the Industry—Varieties Utilized—Harvesting of the Seaweed—The Manufacture of Potassium Salts and Iodine from Seaweed—Incineration Process—Lixiviation and Crystallization Process—The Destructive Distillation of Seaweed—The French Iodine Industry—Importance and Location of Industry—Varieties of Seaweed Utilized on the French Coast—Composition of the French Seaweeds—Harvesting—Drying and Burning of the Seaweed—The Manufacture of Iodine and Potassium Salts from Varec—Japanese Processes—Geographical Distribution

PAGE

and Economic Importance of Industry—Species of Algæ Used—Composition—Harvesting—The Burning of the Seaweed—Extraction of Ash and Recovery of Iodine and Potassium Salts.

CHAPTER 5.—POTASH FROM KELP—THE PACIFIC COAST INDUSTRY 88

Introduction—Physiology of the Kelp Plant—The Composition of the Giant Kelps—Commercial Utilization of Kelp on the Pacific Coast—Kelp as a Direct Fertilizer—The Recovery of Potash by Incineration of Kelp—The Destructive Distillation of Dry Kelp—Commercial Fermentation of Kelp—General Operations of the Hercules Powder Company's Plant—The Future of the Kelp Industry.

CHAPTER 6.—EDIBLE ALGÆ AND THE AGAR-AGAR INDUSTRY . . 111

Importance of Algæ Used as Food—Composition of Edible Algæ—Proteins of Seaweeds—The Ether Extract Content of Algæ—Carbohydrates—Ash Content—Digestibility of Algæ—Carbohydrates—Nitrogenous Constituents—Utilization of Algæ as Food in America—The Irish Moss Industry—The Scituate, Massachusetts, Industry—Dulse—Seatron from *Nereocystis Luetkeana*—Seaweeds Eaten in Europe—The Oriental Edible Algæ Industry—Preparation and Use of Amanori or Red Laver—Kombu—Miscellaneous Edible Japanese Algæ—The Edible Seaweeds of Hawaii—Algæ Eaten in Other Parts of the World—The Agar-Agar Industry—The Nature and Importance of Agar-Agar—Properties of Agar-Agar—Purification of Agar—Species of Algæ Used—Gelose Content of Algæ—Commercial Application of Agar—The American Agar Industry—The Japanese Kanten Industry—The Japanese Method of Manufacture.

CHAPTER 7.—THE MANUFACTURE AND UTILIZATION OF ALGINIC ACID AND OTHER MISCELLANEOUS VEGETABLE PRODUCTS FROM THE SEA 134

Algin—The Chemical and Physical Properties of Algin and Sodium Alginate—Processes of Manufacturing Algin—Stanford's Process—Hercules Powder Company's Process—Uses of Alginic Acid and Alginates—Other Miscellaneous Vegetable Products from the Sea—Seaweed as Manure—Composition and Value of Seaweeds as Manure—Algæ Used for Stock Feed—Seaweeds Used in the Sizing of Cloth—Funori—Marine Plants Used for the Making of Mattresses and Upholstery—Odd Uses for Seaweeds.

CHAPTER 8.—PEARLS AND THE PEARL INDUSTRY—PEARL ESSENCE 146

Introduction—Importance of Industry—The Origin and Growth of Pearls—The Composition and Properties of Pearls

PAGE

—The Fisheries—Methods—Persian Gulf Industry—Ceylon Fisheries—Fishing in the Red Sea—The Venezuelan Fisheries—The Panama Fishery—The Mexican Fishery—The California Abalone Fishery—The Australian Fisheries—The Malaysian Pearl Fishery—Other Pearl Fisheries—Evaluation of Pearls—Utilization in Jewelry—Drilling—Stringing—Mounting—Pearl Essence—History of the Industry—Composition and Preparation of Pearl Essence.

CHAPTER 9.—MOTHER-OF-PEARL AND BLISTER PEARLS OF MARINE ORIGIN 167

Structure and Composition—The Mother-of-Pearl Fisheries—Species of Mollusks Utilized—Geographical Distribution of Mother-of-Pearl Shell Fisheries—Pearl Oysters—*Margaritifera Vulgaris* (Jameson)—*Margaritifera* (Various Species)—White Shells—Yellow Shells—Green Shells—Black Shells—Green Snails (*Turbo Marmoratus*)—*Trochus*—*Haliotis* (Abalones)—Australian Pearl Fisheries—Society Islands—Philippine Pearl-Shell Fisheries—Trochus Shell Fisheries—The California Abalone Fishery—Japanese Mother-of-Pearl—The Chank Fishery of India—Classification of Shells—Manufacture of Buttons—Manufacture of Inlaid Objects—Cameos—Jewelry and Miscellaneous Objects—Preservation—Blister Pearls—Origin—Utilization.

CHAPTER 10.—THE PRECIOUS CORAL INDUSTRY 190

History of the Coral Industry—Importance of Industry—Nature of Coral—Living Coral—The Coral of Commerce—Coral Fishing—Location of Industry—Methods of Fishing—Mediterranean—Japanese Methods—Grading of Coral—The Working of Coral—Utilization in Jewelry.

CHAPTER 11.—CHARACTERISTICS OF MARINE FISHES 200

Definition—Anatomy—The Color—The Foods—Migrations—Geographical Distribution—Spawning and Reproduction—Larval Development—Effects of Fishing—The Geographical and Vertical Distribution of Some Important Commercial Fishes of the United States.

CHAPTER 12.—THE IMPORTANCE OF THE FISHERIES 227

Importance of the Fisheries—Fisheries of the United States—Fisheries by Groups—The More Important Fisheries—Imports and Exports—Fisheries of Canada—Fisheries of the United Kingdom—Fisheries of Norway—Fisheries of Japan.

CHAPTER 13.—FISHERY METHODS AND GEAR 239

Relative Importance of Gear—Apparatus of Capture—Seines—Lines—Pound Nets, Trap Nets, and Weirs—Gill Nets—

PAGE

Otter Trawl and Other Bag Net Trawls—Other Fishery Apparatus—Relative Importance of the Various Classes of Gear—Domestic Production of Fish Nettings—Gear of Foreign Fisheries—Net Preservation.

CHAPTER 14.—FISH AS FOOD—CHARACTERISTICS OF FRESH FISH: APPEARANCE, CHEMICAL COMPOSITION AND NUTRITIVE VALUE . 263

Physical Characteristics—Chemical Characteristics of Fresh Fish—Proximate Composition—Nature of Constituents—Nitrogenous Compounds—Composition of Roe—Nutritive Value—Digestibility—Modern Concepts of Nutrition—Vitamin Content—The Nutritive Value of Fish Proteins—Summary.

CHAPTER 15.—REFRIGERATION AND COLD STORAGE OF FISH . . 280

Importance of Refrigeration—The Nature of the Preservation of Fish by Freezing—Layout, Construction, and Mechanical Equipment of Fish Freezing Plants—Construction and Location of Freezers—Mechanical Refrigeration—The Process of Freezing and Storing of Fish—I. In Air—Preliminary Handling Aboard Boats—Landing, Inspecting, Grading, Washing, Panning, etc.—Freezing in the Sharp Freezer—Glazing—Cold Storage—Packing, Shipment, Defrosting, Cooking—II. Other Methods of Freezing Fish—Brine Freezing.

CHAPTER 16.—THE PRINCIPLES OF FISH SALTING: THE SALTING OF COD AND OTHER GROUND FISH 307

Principles of Fish Salting—The Preservative Action of Salt—The Composition of Salt—Commercial Methods of Salting Fish—Influence of Methods of Cleaning—The Storage of Salted Fish—A Method of Salting Fish in Warm Climates—The Salting of Cod and Other Ground Fish—Location of Industry—Methods of the New England Industry—Salting—Hard Dried Cod—Slack Salted Cod and Pollack—Haddock, Hake, Pollack, and Cusk—Pacific Coast Industry—Statistics—The Vessel Fishery—Shore-Station Methods—Curing at Home Station—Salted Cod Tongues—Barreled Salt Cod.

CHAPTER 17.—SALTING OF OTHER FISH: HERRING, ALEWIVES, MACKEREL, SALMON, MULLET, AND OTHER FISH 327

Introduction—The Salting of Herring—American Methods—The Scotch-Cure as Practiced in America—Herring Salting in Scotland—The Norwegian Cure—Dutch Methods—The Salting of Alewives—Location of Industry—Dry-Salting Process—The Brining of Alewives—Corned River Herring—The Salt Mackerel Industry—Japanese Methods—Whiting—The Salting of Salmon—Mild-Curing—Pickling—Siberian and Japanese Methods—Mullet—Brine-Salted Mullet—Kench-Cured Mullet—Miscellaneous Fishes—Salted Dried Yellowtail.

PAGE

CHAPTER 18.—THE PRESERVATION OF FISH BY SMOKING AND DRYING 348

The Smoking of Fish—The Industry—Smoke-Houses—The Production of Smoke—Smoking Processes—Chemistry Involved in the Preservation of Fish by Smoking—The Smoking of Herring—American Methods of Smoking Herring—Hard or Red Herring—Bloaters—Kippered Herring—Foreign Processes of Smoking Herring—The Smoking of Alewives or River Herring—The Smoking of Haddock—Location of Industry—Scotch Method of Preparing Finnan Haddie—American Method of Preparation of Finnan Haddie—The Smoking of Salmon—Kippered Salmon—Foreign Methods—The Smoking of Halibut—The Smoking of Mackerel—The Preparation of Smoked Eels—The Smoking of Sturgeon and Other Fish—Japanese Method of Smoking Bonito and Tuna—Trepang—Filipino Method—Chinese Method—Other Smoked Fish Products—The Preservation of Fish by Drying—The Location and Importance of the Industry—Principles of Dehydration—Storage of Dried Fish—Oriental Methods—Fish-Drying in Bengal—Japanese Dried Fish Products—Drying of Fish in the Hawaiian Islands—The Modern Dehydration Process—Principles of Modern Dehydration Applied to the Dehydration of Fish—The Dehydration Process—Character of the Product.

CHAPTER 19.—CANNING OF FISH AND FISH PRODUCTS 377

Outline of Canning Methods—The Salmon Canning Industry—Value and Importance—Catching the Salmon—Transportation of the Salmon—The Canning Process—The Canned Product—The Bacteriology of Salmon—Sardines—Canning Methods—The Maine Industry—California Sardines—Chemistry and Bacteriology—Oil for Sardines—Norwegian Sardine Canning—The French Sardine Industry—Tuna—Canned Mackerel—Herring—Shad—Fish Flakes—Fish Roe.

CHAPTER 20.—MISCELLANEOUS PROCESSES OF PRESERVING FISH . 404

Variety of Products—Fish Pickled in Vinegar or Marinated Products—Principle of the Use of Vinegar—Russian Sardines—Fried Marinated Fish—Bismarck Herring—Japanese Pickled Fish—Fermented Fish Products—Anchovy Paste—Fish Sausages—Christiania Anchovies—German Delikatessen (Anchovies)—Caviar—American Processes of Manufacture—Caviar Manufacture in Russia—Dried Mullet Roes—Shark Products—Shark-Flesh Paste—Preservation of Shark Fins—Japanese Canned Fish Pudding.

CHAPTER 21.—FISH BY-PRODUCTS. FISH OILS 415

Importance and Location of the Industry—General Characteristics—Menhaden—The Industry—Methods of Manufacture—

PAGE

Pressing—Yield of Oil—Grades of Oil—Refining—Composition—Uses—Sardine and Herring Oil—The Industry—Methods of Manufacture—Characteristics of Sardine Oil—Japanese Sardine Oil—Manufacture of Herring Oil—Composition of Herring Oil—Salmon Oil—The Industry—Methods of Manufacture—Characteristics of Salmon Oils—Uses—Oils of Minor Importance.

CHAPTER 22.—LIVER OILS 442

General Characteristics—Cod-Liver Oil—Methods of Manufacture—Electrolytic Extraction—Properties—Uses of Cod Oil—Shark-Liver Oil—Location of Industry—Properties—Uses—Dogfish-Liver Oil—Properties—Liver Oils of Little Commercial Importance.

CHAPTER 23.—FISH SCRAP FERTILIZER 456

The Industry—Methods of Manufacture—The Preparation of Menhaden Scrap—The Manufacture of Scrap from Other Fish—Special Apparatus—Composition of Scrap—Availability.

CHAPTER 24.—FISH MEAL 465

The Industry—Methods of Manufacture—Storage—Composition—Nutritive Value—Use.

CHAPTER 25.—FISH GLUE AND ISINGLASS 476

The Manufacture and Properties of Fish Glue—Importance and Location of the Industry—The Chemistry of Fish Glue Manufacture—Source of Raw Materials—Methods of Manufacture—Skin Glue—Waste Glue—Fish Head Glue—Composition—Examination of Liquid Glue—Methods of Examination—By-Products—Uses—Fish Isinglass and the Isinglass Industry—Location of Industry—Raw Materials—Methods of Manufacture—Russian Isinglass—American Methods—Composition and Properties of Isinglass—Uses.

CHAPTER 26.—MANUFACTURE OF LEATHER FROM MARINE SOURCES 492

Sealskins—Sharkskin Leather—Porpoise Skins—Miscellaneous Leathers—Chemical Reactions Involved in Tanning.

CHAPTER 27.—THE WORLD'S OYSTER INDUSTRY 504

Distribution of the Oyster Industry—Oyster Fisheries of North America — United States — Canada — Mexico — South America—Europe—Asia—Africa—Australia and New Zealand—Philippine Islands—Statistics—The World's Oyster Fishery—United States—The Growing of Oysters—Life History—Factors of Environment—General Habitat and Distribution—Salinity—Trade Wastes—Silt—Bottom—Enemies—Spat Col-

PAGE

lecting—Growing and Conditioning—Taking Oysters from the Beds—Unloading the Oysters—Marketing Raw Oysters—Shucked Oysters—Shell Stock—Canning—Other Preservation Methods—By-Products—Chemical Composition of Oysters—Changes During Canning and Storage—Danger of Infection from Eating Raw Oysters.

CHAPTER 28.—THE CLAM INDUSTRY OF THE UNITED STATES . . 532

The Commercial Importance of the Clam—Species of Clams Commercially Utilized—Life Histories of Most Important Species of Clams Utilized Commercially—Chemical Composition of Clams—Contamination by Pathogenic Organisms—Clam Culture in New England—Razor Clam Cultivation in Japan—The Atlantic Coast Industry—Soft Clam—Hard Clam Fishery—The Pacific Coast Clam Industry—Preservation of Clams—Canning—By-Products.

CHAPTER 29.—THE AMERICAN SHRIMP INDUSTRY 548

The Fishery—Composition—Marketing—Shrimp Preservation—Canning—Drying.

CHAPTER 30.—THE AMERICAN CRAB INDUSTRY 561

History of the Fishery—Species of Economic Importance—Life History of the Blue Crab—The Atlantic Coast Fishery—Location—Seasons—Methods of Fishing—Marketing—Preparation for Market—Pacific Coast Fishery—Methods of Fishing—The Canning of Crab Meat—By-Products.

CHAPTER 31.—THE LOBSTER FISHERY 577

Early History of the Fishery—Location of the Present Industry—The Decline of the Fishery—Life History of the Lobster—The Larval Stages—Habits of the Adult Lobster—The Color of Lobsters—Propagation of Lobsters—Need of Artificial Propagation—Methods—Chemical Composition and Nutritive Value of Lobsters—Fresh Lobsters—The Composition of the Shell of the Lobster—The New England Lobster Fishery—Methods of Fishing—Preservation of Live Lobsters—Transportation of Live Lobsters—Boiling—The Canadian and Newfoundland Lobster Fishery—The Live Lobster Industry—The Canning of Lobsters—American Spiny Lobster Fishery—The European Lobster Fishery—The Development of the Fishery—Varieties of Lobsters Caught in European Waters—The Present Extent of the European Fishery.

CHAPTER 32.—MARINE TURTLES AND TERRAPINS 596

Location and Importance of Industry—The Green Turtle Fishery—The Key West Turtle Fishery—The Costa Rican Fishery

PAGE

—The Hawks'bill Turtle Fishery—The Manufacture of Tortoise Shell—The Loggerhead Turtle—Other Marine Turtles—The Diamond-Back Terrapin—The Decline of the Terrapin Fishery—Habits and Propagation of Terrapins—Methods of Fishing—Marketing.

CHAPTER 33.—MISCELLANEOUS SHELLFISH INDUSTRIES OF THE UNITED STATES 607

Scallops—Species of Commercial Importance—The Chemical Composition of Scallops—The Scallop Fishery—The Small or Bay Scallop—By-Products—The Giant or Sea Scallop Industry—The California Abalone Industry—The Development of the Industry—Physiology and Habits of the Abalones—Fishing—Utilization of Abalones—Fresh Abalones—Dried and Smoked Abalones—Canning—By-Products—Sea Mussels—Possibilities of the Industry—Species of Mussels Utilized—Composition of Sea Mussels—Utilization of Mussels—Fresh—Pickled Mussels—The Canning of Mussels—Other Uses for Mussels—Other Shellfish Industries.

CHAPTER 34.—THE WHALING INDUSTRY, PORPOISES AND DOLPHINS 625

Whales—Characteristics—Economically Important Species—The Industry—Location and Importance—Methods of Capture—Butchering—Meat for Man—Whale Oil—Composition and Properties — Use — Sperm Oil — By-Products—Spermaceti—Arctic Sperm Oil—Scrap—Whalebone—Miscellaneous Products—Dolphins, Porpoises, and Brown-Fish—Characteristics and Uses of Oils.

CHAPTER 35.—SEALS AND WALRUSES 647

History of Fur Sealing—Sealing in the Southern Hemisphere—Northern Seal Herds—Development of Pelagic Sealing—Species of Fur Seals—Habits of Fur Seals—Sealing Methods on Pribilof Islands—Federal Protection—Killing—Skinning—Handling of Pelts—Disposition of Carcasses—Fur Seal Markets—Classification and Grading of Pelts—Preparation of the Fur—By-Products—Hair Seals and Sea Lions—Species of Economic Importance—List of Hair Seals, Sea Elephants and Sea Lions—Habits—Methods of Seal Hunting—Location and Importance of Industry—Preparation of Seal Oil—Composition and Properties of Seal Oil—Walrus—Importance and Location of Industry—Species of Walrus—Habits of the Walrus—Methods of Hunting Walrus—Products—Preparation of Walrus Oil.

CHAPTER 36.—COMMERCIAL SPONGES 668

History of the Industry—Statistical—The Living Sponge—Description of Commercial Sponges—Chemistry of Sponges—

PAGE

Sponge Culture—Commercial Varieties of Sponges—Sheepswool or Wool Sponges—Yellow Sponges—Velvet Sponges—Grass Sponges—Glove Sponges—Wire Sponges—Reef Sponges—Hardhead Sponges—Turkey Cup and Turkey Solid Sponges—Turkey Toilet Sponges—Zimocca Sponge—Honeycomb or Bath Sponges—Elephant-Ear Sponges—Methods of the Fishery—Nude Diving—Hooking and Harpooning—Machine Diving—Dredging or Trawling—Preparation of Sponges for Market.

CHAPTER 37.—SOME PROBLEMS OF THE FISHERY INDUSTRIES . . 692

APPENDIX I.—1. STATISTICS OF THE FISHERIES BY STATES . . 703

2. CANNED FISHERY PRODUCTS OF THE UNITED STATES AND ALASKA, 1922 723

APPENDIX II.—LIST OF COMMON NAMES AND DESCRIPTIONS OF MARINE FISH AND ANIMALS OF COMMERCIAL IMPORTANCE OF THE UNITED STATES AND ALASKA 727

MARINE PRODUCTS OF COMMERCE

Chapter 1.

Economic Importance of Marine Products.

The Sea.

The sea covers three-fourths of the earth's surface, and is so vast that few can comprehend its size, being about 139,000,000 square miles in area and 302,000,000 cubic miles in volume. To the casual observer the ocean appears as a barren waste valued chiefly for transportation and source of rainfall. Yet it is veritably teeming with both plant and animal life.

The largest animals and the tallest plants grow in the ocean. Nowhere else can such large quantities of excellent food be obtained for such little effort.

Importance of Marine Products in History.

Many marine products have been utilized since prehistoric times. Amber, coral, salt, fish, and shellfish were among the first articles to be bartered by savage man. Wampum or strings of shell beads served as money among many tribes of the North American Indians.

Sea fishery is generally considered the cause that first led man to sail upon the ocean and from this beginning all maritime nations have had their rise. Such was the origin of the fleets of the Phœnicians and the early Greeks. The Norsemen on the cold, barren shores of Scandinavia were forced to become expert fishermen or starve. Britain's great fleets had their origin on the fishing banks of the North Sea.

In Medieval times, the fisheries were relatively more important than they are to-day. In those days, the quantity of fish taken was much less; but since manufacturing and agriculture were in the early stages of development, the human race was more dependent upon the products of the sea. Whale oil and spermaceti were essential for illuminants. Relatively little land was tilled, therefore fish was a much more important food.

Fishing rights have always been a source of international rivalry and disputes, and have caused many wars. In 1348, when the Danes imposed a customs duty upon all imports of herring, the Hanseatic cities immediately declared war upon them. Throughout the seventeenth century, the herring fisheries were the cause of much contention between the British and Dutch. Even in recent years, the Bering Sea fisheries have caused disputes between Great Britain, Japan, and the United States.

Our own country owes much to the fisheries, for the early settlers on the rockbound New England coast had great difficulty in obtaining sufficient food, and might have starved had it not been for the discovery of the rich fishing grounds close at hand. The proximity of the banks encouraged the building of vessels and so the New Englanders became the pioneer seamen of America. The schooner, the fastest of all commercial sailing vessels, was invented, and is used yet, by the fishermen of Gloucester, Massachusetts.

Relative Importance of Marine Products.

Our only sources of food, upon which life is dependent, are agriculture and fisheries, the wild game of the forests no longer being a factor of economic importance. While the fisheries are nearly overshadowed by agriculture, yet they furnish products which could be dispensed with only with difficulty. The crops need not be sown nor cultivated yet furnish a bounteous harvest for the taking. Moreover, the annual product has been rapidly increasing in both quantity and value in recent years. The limit of production has not been reached and with careful supervision, the fisheries may be expanded greatly. The most reliable statistics available indicate that the annual products of the world's fisheries are valued in excess of a billion dollars. In making up the total for marine products, at least a hundred million dollars may be added to this, as the value of the salt, iodine, potash, pearls and miscellaneous products is not usually included in the evaluation of the fisheries.

It has been estimated that, taken as a whole, fishery products constitute less than three per cent of the world's food. However, in certain countries, as Norway and Japan, fish is a much more important food factor and may even make up ten per cent of the food.

England, Japan, and the United States each produce about one hundred million dollars' worth of fishery products annually. In England and the United States, the industries are relatively small compared to agriculture, mining, and manufacturing. In England, the chief fisheries are those for herring, cod, haddock, and mackerel. The more important catches of fish in American waters include those listed above and also salmon, sardines, halibut, menhaden, shad, alewives, and oysters, shrimp, and lobsters.

In Japan, the marine fisheries occupy a place of importance comparable to that of no other large nation. In spite of the small area of land, the coast line is extraordinarily long, being more than 20,000 miles in extent. The islands are rather mountainous, consequently the agricultural products are limited and since there are about 55,000,000 inhabitants in an area of only 260,738 square miles, the Japanese are forced to look to the sea for a considerable proportion of their food. Japanese statistics indicate that about two million men,[1] entirely or partly, are engaged in the fisheries. The great number of people employed in these industries is accounted for

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[1] 1,400,000 were employed full time and about 600,000 devoted part of their efforts to fishing or in the fishery industry.

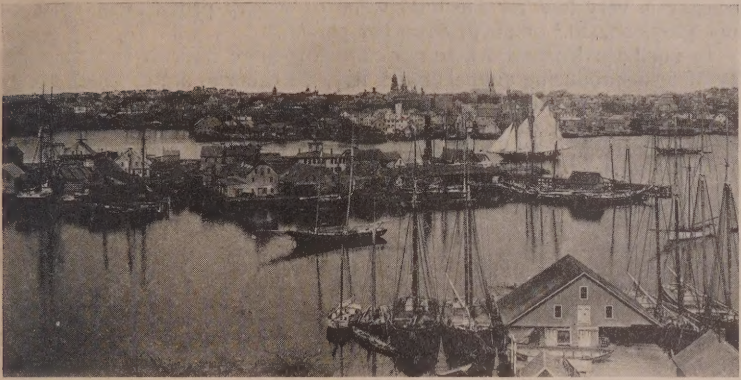

FIG. 1.—Gloucester Harbor, America's oldest fishing port. This city, founded by fisher folk in 1623, has been one of the leading fishing centers ever since. Here the schooner was invented; many are always to be seen in the harbor.

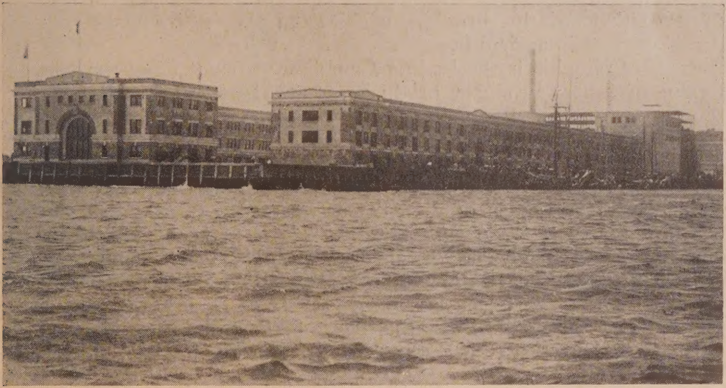

FIG. 2.—The Boston Fish Pier. Recently, Boston has taken first place among America's fishing ports and has constructed this, the finest fish pier.

by the fact that every part of Japan is directly or indirectly related to and interested in fisheries. The annual product per person engaged in the industry is very low for the total value of fishery products in 1919 was only $205,000,000,[2] or about $100 per person.

In northern Europe, where agriculture is more difficult and the quantity of meat-producing animals much less, the fisheries are of much greater national importance than in America. Fishing is the one great industry of Norway and one of the leading industries of Scotland.

The Norwegians catch about a million and a half barrels of herring each year having a value of about 10,000,000 kroner ($2,680,000). Cod, haddock, flounders, and sardines are also caught in enormous quantities by the Norwegians. The Norwegians control about half of the world's whaling industry.

Denmark and Iceland also have exceptionally important fisheries when their population and size are considered.

Newfoundland and Labrador offer one of the best modern examples of a people living from one resource, that of fish. Fishery products, chiefly dried cod, constitute about eight-ninths of the exports of this northern dependency of Great Britain. There is a little iron mining, a little lumbering and paper making, but ninety per cent of the workers are engaged in the fisheries. The climate is so cold and damp that there is little agriculture. The people who are not at sea catching cod, haddock, or herring are busy curing them or preparing fishing gear or boats.

The fisheries of Nova Scotia are also very extensive, having an annual value of about $15,000,000 and are one of the leading industries. The warmer climate of this province enables the people to engage to a considerable extent in agriculture.

British Columbia is the leading Canadian province from the viewpoint of value of fishery products, producing nearly half the Canadian total.

Variety of Products.

Fish.—Fish are marvelously abundant. Thousands of species exist whose names are known only to the systematist. It has been estimated that more than 19,000 different species exist, some of which are very numerous, as the menhaden, of which about a billion are caught each year along the Atlantic coast and Gulf of Mexico. The herring fisheries of the North Sea have yielded enormous quantities of fish for more than a thousand years and still yield more than a billion herring annually.

When the enormous number of fish is considered, one wonders where they obtain sufficient food to satisfy their voracious appetities. However, when sea water is examined under a microscope it is seen that the ocean is veritably alive, for even the clear water has countless millions of minute organisms. Many of these individual plants, which float with the currents, are so minute as to be invisible to the naked eye. Indeed, the majority of these floating plants pass their lives as single cells, though they are frequently far more highly organized than the single cells that go to form a higher plant.

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[2] Value of all marine products for the Japanese Empire including Korea. See *Résumé statistique de L'Empire du Japon, 36* (1922).

Enormous numbers of minute pelagic animal organisms also occur distributed throughout the ocean at all depths, although the numbers are much greater near the surface and in relatively shallow water. This pelagic animal life is of all forms from the unicellular protozoa to the fishes; even to mention them all would be to write a treatise on marine zoology.

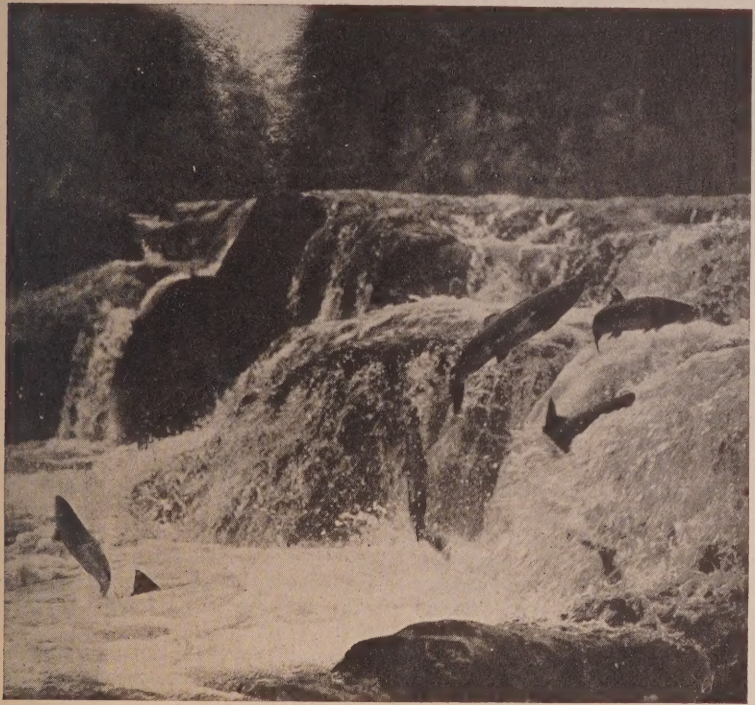

Fig. 3.—Salmon jumping a falls in their effort to get upstream to spawn. The salmon fishery is the most important in America.

The pelagic plant and animal life as a whole has been designated plankton and this is the source, either directly or indirectly, of the food of all marine animal life. It is the quantity of these minute forms which is the factor limiting the number of fish that a given area can support. The animal plankton lives at the expense of the vegetable plankton. The larger marine animals consume either vegetable or animal plankton, or animals smaller than themselves which are nourished on the small pelagic organisms.

Thus it is evident that fish are absolutely dependent upon the vegetable plankton for life. These minute plants have the power to absorb the dissolved nitrogenous compounds (nitrates, nitrites, and ammonia), mineral salts and carbon dioxide and thus fabricate living matter. Obviously, there is a great excess of mineral salts and carbon dioxide in sea water. The factor limiting the growth of the vegetable plankton is the nitrogenous matter. The chief source of this is that carried in by the rivers. Therefore marine life is more abundant near the shore and especially near the mouths of large rivers, other factors being equal.

Fish are utilized principally as food for man. In addition to being eaten fresh, they are preserved by freezing, canning, salting, pickling, smoking, and even fermenting. Non-edible fish are made into oil, fertilizer and meal. Fish and fish liver oils find many commercial applications. Hydrogenated or hardened fish oil is largely used for soap manufacture. The swim bladders of certain fish are made into isinglass. Cod, cusk, hake, pollack, and haddock skins and waste are utilized for glue manufacture. The skins of shark and a few other fish are tanned into excellent leather. Shad, alewife and other fishes' scales are used in pearl essence manufacture.

Shellfish.—Mollusks are utilized to an extent scarcely appreciated by many people. In America, the annual product of these fisheries constitutes approximately one-third of the total value of all the fisheries. The oyster industry yields, in addition to about $15,000,000 worth of a nutritious food product, several millions of dollars worth of poultry grit, lime and fertilizer. The fresh-water mussel industries of the Mississippi Valley produce mother-of-pearl buttons and other useful ornaments valued at over $5,000,000. Our clam, scallop and abalone fisheries are also fair sized industries. There appears to be an unfounded prejudice against the edible qualities of sea mussels. An industry greater than that of the oyster fishery might be developed if Americans would eat this shellfish as do the Europeans.

The world's pearl and pearl shell industries are of great importance, the annual production certainly being in excess of $50,000,000. The Australian fisheries are of particular importance. Pearls have great value, particularly in the large cities of Europe and America, single strings of pearls occasionally bringing half a million dollars.

Crustacea.—Lobsters, crabs, and shrimp are now universally esteemed as food. Fifty years ago the blue crab was almost unknown as an article of food. Its rise to importance has been rapid, about fifty millions of pounds now being taken annually. Lobsters have been so much in demand that their numbers have been seriously diminished. The Atlantic Coast of Canada remains the only large producer. Within the last few years canned shrimp has become very popular in America. Because of this fact, the fishery has undergone a sudden expansion.

Seal Fur and Leather.—The demand for beautiful fur encouraged the pelagic sealers to search every known rookery for these valuable aquatic mammals and to follow them everywhere on the high seas, until the fur seal was nearly exterminated. International agreement between Japan, Great Britain, Russia, and the United States ended pelagic sealing in 1912 and saved the fur seal. Now the United States has an annual revenue of nearly a million dollars a year from the Pribilof Island rookeries.

Hair seals and walrus furnish hides from which valuable leathers are prepared.

Whale Oil and Meal.—Whaling played a very important part in the early economic history of our Republic. The New Bedford whalers cruised the seven seas in search of whales and furnished a large part ot the world with illuminating oil, candles and whalebone. With the discovery of petroleum, the importance of deep-sea whaling rapidly diminished. The invention of the harpoon-gun in 1874 gave the industry new life and the discovery of practical means of hardening the oil by hydrogenation about a decade ago brought the fishery to the point where $70,000,000 worth of whale products are prepared annually. Now the whales are threatened with extinction, and, unless the reckless slaughter is stopped by international agreement, the whale will cease to be of economic importance within a decade or two.

Porpoises, dolphins and blackfish furnish valuable oil and leather, but as relatively few are captured in any one locality, the fishery is of little commercial importance.

Tortoise-shell.—Turtle fisheries are prosecuted in nearly all tropical waters, and in addition to the valuable meat obtained from the green turtle, afford a valuable ornamental material, tortoise-shell, which is procured from the shields of the carapace of the hawk'sbill turtle.

Sponges.—The sponge fisheries are of importance at Key West, Nassau, Algeria and in the Mediterranean. The limited extent of the fishery together with the great demand for sponges keeps the price high. Sponges can be cultivated and, if more interest were given to the fishery, an industry of great commercial value might be developed.

Coral.—The Japanese and Italian coral fisheries have furnished a valuable ornamental material for many centuries. Formerly the Mediterranean Sea yielded the major portion of the world's production but in recent years the Japanese have increased their production greatly.

Salt and By-Products.—For countless centuries the rain has leached through the soil and rock forming the earth's crust, and has dissolved enormous quantities of minerals, washing first into the streams and rivers and thence into the ocean. Thus, while river water is a very dilute solution and does not taste salty, the ocean contains the accumulation of salts brought in by the rivers during the millions of years since rain first fell upon the earth. The human mind has difficulty in conceiving of the quantities of salts in the ocean. It has been estimated that the total salts in the ocean weigh about $48,188 \times 10^{12}$ metric tons. By estimating the quantity of salts carried in annually by the rivers various geologists have attempted to calculate the geologic age of the world. In this way they conclude that the world is about 100,000,000 years old. The enormous rock salt deposits in Stassfurt, Cheshire, the Great Lakes Region and elsewhere are but the remains of ancient inland seas. From time to time man's cupidity has been aroused by clever swindlers who claim they have found a short cut to wealth by a novel way of extracting gold, silver, iodine, and other valuable elements from the sea. Fortunes have been made from the sea but not by extracting elements or compounds present in very small proportions.

The sea is a great potential source of common salt, potassium, magnesium and calcium salts, iodine and bromine. At present, common salt is the most important inorganic product obtained by the evaporation of sea water, some being prepared in almost every country in the world. While salt is usually a cheap product it is essential for human life, and therefore its manufacture is always of importance.

In hot arid countries where large tracts of level land lie close to the sea, salt-making is usually carried on on a large scale. In certain districts of Portugal, Spain, France, China, and California there are valuable salines. Valuable by-products such as potassium and magnesium salts and iodine may be prepared from the mother liquors remaining after the crystallization of the salt. As yet, the industries have been slow to utilize these salts. In California, some potash is recovered and a valuable magnesium oxychloride cement is manufactured in large quantities from the bittern.

Vegetable Products.—So eminent an authority as Professor Shaler[3] of Harvard has estimated that the vegetable matter of the seas is equal in quantity to the plant growth of the land. Some of the multitudinous species of marine vegetation are fastened to the bottom, others, in great variety, float in the water—drifting in its currents. These marine plants draw their inorganic nutriment from the sea through the general surface of their bodies and not through roots.

Marine plants are utilized scarcely at all. The kelp burners of Scotland, France, Norway, and Japan produce about a third of the world's iodine and a few thousand tons of potash. Limited amounts of seaweed are used as fertilizer along the seacoast in the British Isles, Europe, Japan, and elsewhere. In Scotland, Norway, and in other places where forage crops are scarce and dear, algæ are occasionally fed to stock. In many countries lying close to the coast where vegetables are relatively high in price, as in Japan, Hawaii, and the British Isles, seaweeds have a regular place in the dietary of certain classes of people. Irish moss is a favorite seafood in certain districts of England, Ireland, Scotland and the United States. Agar is also commonly used for the preparation of blanc mange although it is rather expensive.

Seaweeds are more extensively utilized in Japan than in any other country of the world, and, if they were harvested in similar quantities in other parts of the world, the annual production would reach a very high figure indeed. In addition to being almost universally eaten, algæ find numerous other uses in Japan. An important glue, or size, *funori,* is manufactured from certain species. Agar-agar or *kanten* is prepared on a large scale. This substance in addition to being a food finds extensive use for the preparation of media for bacterial growth and as a medicine.

In recent years, many novel uses have been suggested for various algæ but none seems to have been generally adopted. Algin, which occurs in many seaweeds in considerable quantities, has been found to possess unusual properties, making it a valuable substance. Upon fermentation, the Pacific Coast kelps yield compounds from which acetone and numerous other valuable solvents may be prepared, and upon destructive distillation, in addition to potash, a decolorizing carbon, ammonia liquor and several other valuable products are obtained.

[3] Man and the Earth, New York, 1905.

When the tremendous quantity of marine vegetation is considered, the present uses to which it is put seem infinitesimal by comparison. Its chief purpose seems to be as a store of nutriment for the thousands of forms of marine animal life.

Possibilities.

There are no new lands or oceans to be discovered, so, as the world's population increases, the production of the lands and seas will have to be increased. At present, certain areas are overfished, while others are neglected. Overfishing is particularly dangerous in the case of aquatic animals which remain close to shore at all times, such as crabs, lobsters and the mollusks.

Hundreds of species of fish occur in large quantities which are utilized scarcely at all. Many species of fish such as the dogfish and sharks are very destructive of food fishes. If these could be diminished in number the food fishes would increase.

More extensive fish cultural operations would increase the numbers of food fish.

Thus while the ocean is, and is likely to remain, an unconquered wilderness, as man learns more concerning its animal and vegetable life, it may be made to contribute more than it now does to the welfare of man.

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Chapter 2.

Salt from Sea Water.

Introduction—The Composition of Sea Water.

The composition of sea water has been the subject of many elaborate analytical investigations. These investigations have shown that, although ocean water varies considerably in concentration, the composition of the saline matter which it contains is remarkably uniform.

Sea water is mainly a solution of the chlorides and sulphates of sodium, magnesium, calcium, and potassium, although it contains appreciable amounts of bromine, iodine, iron, silicon, carbonate and phosphate. The presence in it of fluorine, nitrogen, arsenic, boron, lithium, rubidium, caesium, strontium, manganese, barium, aluminium, copper, zinc, silver, lead, cobalt, nickel, gold and radium have been demonstrated.

Clarke[1] has tabulated many of the recent analyses of sea water from different parts of the world; whose tabulation of them is presented in the following table in which the percentage composition of the anhydrous residues of the waters is given. The total content of inorganic matter of each sample is given below and is expressed in percentage.

TABLE I

Analyses of Oceanic Salts

A. Mean of 77 analyses of ocean water from many localities, collected by the *Challenger* expedition, W. Dittmar, analyst. *Challenger Rept., Physics and Chemistry, 1* (1884), 203. Salinity, 3.301 to 3.737 per cent.

B. Atlantic water, mean of 22 samples collected on a voyage from the Cape of Good Hope to England. C. J. S. Makin, *Chem. News, 77* (1898), 155, 171. Salinity average, 3.631 per cent.

C. The Atlantic near Dieppe. Analysis by T. Schloesing, *Compt. rend. 142* (1906), 320. Salinity, 32.420 grams per liter.

D. The Irish Sea. Analysis by T. E. Thorpe and E. H. Morton, *Ann. 158* (1871), 122. The small amounts of Fe_2O_3, NH_3, and N_2O_5 are here added together. A trace of lithium was also reported.

E. The Baltic Sea between Oeland and Gothland. Analysis by C. Schmidt, *Bull. Acad. Sci. 24* (1878), 231. In all Schmidt's analyses the bicarbonates given by him have been reduced to normal salts. The quantities of Fe, PO_4, and SiO_2 found by Schmidt are so small that I have added them together. Salinity of this sample, 0.7215 per cent.

F. The Atlantic at Bahia Blanca, coast of Argentina. Mean of two samples, taken at low and high tide. Analyses by E. H. Ducloux, *Annales Soc. cient. Argentina, 54* (1902), 62. Salinity, 3.365 per cent. Another pair of analyses is given of water taken at the mouth of Rio Negro.

G. The Gulf of Mexico, off Loggerhead Key, near Florida. Analysis by G. Steiger, laboratory of the U. S. Geol. Surv., 1910. Salinity, 3.549 per cent.

H. From near Beaufort, North Carolina. Mean of five analyses of samples taken under varying conditions, by A. S. Wheeler, *J. Am. Chem. Soc., 32* (1910), 646. Salinity, 3.179 to 3.607 per cent. Wheeler cites an analysis by C. Herbst of Mediterranean water.

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[1] The Data of Geochemistry, 4th ed., *U. S. Geol. Survey, Bull. 695* (1920), 118-145.

I. The north Atlantic between Norway, the Faroe Islands, and Iceland, and northward to Spitzbergen. Mean of 51 incomplete analyses by L. Schmelck, *Den Norske Nordhavs-Expedition,* pt. 9 (1882), 1. Soda and carbonic acid estimated by calculation, not directly determined. Salinity, 3.37 to 3.56 per cent.

J. The White Sea. Average of three analyses by C. Schmidt. *Bull. Acad. Sci., 24* (1878), 231. Salinity, 2.598 to 2.968 per cent.

K. The Arctic Ocean between the White Sea and Nova Zembla. Mean of two analyses by Schmidt.

L. The Siberian Ocean. Water collected by the *Vega* expedition. Mean of four analyses by Forsberg, *Vega Exped. Rept., 2* (1883), 376. Salinity, 1.378 to 3.457 per cent.

M. The Mediterranean near Carthage. Analysis by T. Schloesing, *Compt. rend., 142* (1906), 320. Salinity, 38.9744 grams per liter.

N. The Mediterranean, midsea, between Bizerta and Marseilles. Salinity, 38.789 grams per liter. Analysis by Schloesing.

O. The eastern Mediterranean, waters collected during the voyages of the Austrian steamer *Pola.* Analyst, K. Natterer, *Monatsh. 13* (1892), 873, 897; *14* (1893), 624; *15* (1894), 530. Three hundred samples of water were examined, some only for gases. The figures given here are the average from 42 analyses which were fairly complete. Salinity, 3.836 to 4.115 per cent.

P. The Sea of Marmora. Natterer, *Monatsh. 16* (1895), 405; 44 partial analyses. Natterer gives the figures here utilized as averages of varying numbers of determinations. Mg, Na, and K not determined. Salinity, 2.310 to 4.061 per cent.

Q. The Black Sea. Average of six analyses by S. Kolotoff, *J. Russ. Phys. Chem. Soc., 24* (1893), 82. Salinity, 1.826 to 2.223 per cent.

R. The Suez Canal at Ismailia. Analysis by C. Schmidt, *Bull. Acad. Sci. 24* (1878), 231. Salinity, 5.103 per cent. For other data on the Suez Canal, see L. Durand-Claye, *Ann. chim. phys.,* 5th ser., *3* (1874), 188. Very high salinities were noted. For a recent, incomplete analysis of Red Sea water, see J. B. Coppock, *Chem. News, 96* (1907), 212.

S. The Red Sea near the middle. Analysis by Schmidt. Salinity, 3.976 per cent.

T. The Red Sea. Average of four analyses by Natterer, *Monatsh. 20* (1899), 1; *21* (1900), 1037. Water collected in the Suez Canal, the Timsah Lake, and the two Bitter Lakes. Many other partial analyses are given. The salinity of these particular samples ranged from 5.085 to 6.854 per cent.

U. The Straits of Malacca. Salinity, 2.7965.

V. The China Sea. Salinity, 3.208 per cent.

W. The Indian Ocean, mean of two analyses, salinity, 3.5534 to 3.6681 per cent. Analyses U, V, W, by C. Schmidt, *Mel. phys. chem. 10,* 594. Also *Jahresb. Chemie.* (1877), 1370. Schmidt's rubidium determinations need verification.

X. The "Mare Morto," an inclosed body of water on the island Lacromo in the Adriatic, having underground connection with the sea. Salinity, 3.1744 per cent. Analysis by W. Loebisch and L. Sipocz, *Min. Mitt.* (1876), 171.

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
Cl	55.292	55.185	55.04	55.21	55.01	54.62	55.24	55.25
Br	.188	.179	.19	.19	.13	—	.17	—
SO_4	7.692	7.914	7.86	7.69	8.00	8.01	7.54	7.56
CO_3	.207	.213	.18	.09	.14	.27	.34	.37
Na	30.593	30.260	30.71	30.82	3.047	30.20	30.80	30.76
K	1.106	1.109	1.06	1.16	.96	2.10	1.10	1.14
Rb	—	—	—	—	.04	—	—	—
Ca	1.197	1.244	1.27	1.21	1.67	1.36	1.22	1.22
Mg	3.725	3.896	3.69	3.61	3.53	3.36	3.59	3.70
Fe, SiO_2, PO_4	—	—	—	—	.05	—	—	—
Fe, NH_4, NO_3	—	—	—	.02	—	—	—	—
$(Fe, Al)_2O_3$, SiO_2	—	—	—	—	—	.08	—	—
	100.000	100.000	100.00	100.00	100.00	100.00	100.00	100.00

	I	*J*	*K*	*L*	*M*	*N*	*O*	*P*
Cl	55.46	55.22	55.30	55.45	55.53	55.11	55.30	55.45
Br		.14	.14		.18	.19	.16	.17
SO_4	7.59	7.88	7.78	7.79	7.74	7.89	7.72	7.67
CO_3	.30	.10	.07	—	.19	.20	.19	.28
Na	30.53	30.65	30.85	30.41	30.37	30.64	30.51	—
K	1.12	.93	.89	1.17	1.09	1.09	1.12	—
Rb	—	.04	.04	—	—	—	—	—
Ca	1.21	1.21	1.16	1.18	1.26	1.23	1.19	1.22
Mg	3.79	3.75	3.69	3.82	3.64	3.65	3.81	—
Fe, SiO_2, PO_4	—	.08	.08	—	—	—	—	—
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	—

	Q	*R*	*S*	*T*	*U*	*V*	*W*	*X*
Cl	55.12	55.59	55.60	55.96	55.46	55.43	55.41	54.78
Br	.18	.14	.13	.18	.13	.13	.13	.26
SO_4	7.47	7.67	7.65	7.49	7.91	7.76	7.79	7.60
CO_3	.46	.01	.02	.13	.04	.03	.05	.72
Na	30.46	31.21	30.81	30.31	30.23	30.67	30.89	30.57
K	1.16	.64	.97	1.06	.94	.97	.85	1.11
Rb	—	.03	.04	—	.03	.04	.03	—
Ca	1.41	1.05	.89	1.22	1.19	1.19	1.16	1.25
Mg	3.74	3.64	3.87	3.65	4.03	3.75	3.67	3.71
Fe, SiO_2, PO_4	—	.02	.02	—	.04	.03	.02	—
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Many of the differences between the figures given in Clarke's table are no larger than can be ascribed to differences in analytical methods or in the atomic weight factors used for calculation. The waters of the Baltic (E) and the Black seas (Q), with their very low salinity, show the effect of dilution by fresh water from the rivers, which appears in the slightly higher percentage of calcium. However, the essential uniformity in composition of the ocean salts is evident. Inasmuch as Dittmar's results (A) represent the average composition of seventy-seven samples of ocean water, and were taken from many different parts of the ocean and since they were drawn from various depths of water, these results should be taken as the standard for comparison. Dittmar[2] found that the density and therefore the salinity of ocean water diminished from the surface to a depth of 800 to 1,000 fathoms, and then increases to the bottom. Around the poles, there are areas of concentration because of the freezing of the surface which removes nearly pure water and leaves a large part of the salts behind. Since the rivers continually bring small amounts of dissolved mineral matter into the ocean, and the mineral matter of river water is derived from the decomposition of rocks by flowing and percolating waters, it is assumed that the source of the ocean salts is the mineral matter of rocks which have been eroded by the continual weathering.

Since we can estimate with some exactness the total amount of sodium in the sea, if we assume that it has been added in a constant manner without serious losses, we can estimate the age of the ocean if we know the annual amount of sodium added by the rivers. Joly[3] in 1899 estimated the age of the ocean by dividing the total estimated amount of sodium in the ocean by the annual amount added by the rivers and obtained the figure 89,222,900 years. Clarke[4] has discussed Joly's calculations in the light of the most reliable figures obtainable at the present time, and after making allowance for various possible errors, concludes that "the age of the ocean, since the earth assumed its present form, is somewhat less than 100,000,000 years."

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[2] *Challenger Report, 2* (1882), 948-1003.

Gold, silver and radium are among the elements contained in sea water. The amounts of these elements which are found are very small and are ordinarily listed as traces. Nevertheless, their presence in sea water has attracted much attention.

E. Sonstadt[5] in 1872 was the first to find a trace of gold in sea water. Numerous observers have verified his observation. C. A. Münster[6] found 5 to 6 milligrams of gold and 19 to 20 milligrams of silver per ton of water from the Kristiania Fjord, Norway. Liversidge[7] analyzed Australian waters and found gold to the extent of 0.5 to 1.0 grains per ton. References to results by other chemists are given below.[8]

Inasmuch as sea water, salt and oceanic sediments are all more or less radioactive, various observers have concluded that they contain radium. Joly has estimated that 1 cc. of sea water contains on the average 0.017×10^{-12} gram of radium. However, there is no evidence to show that this radioactivity is due solely to radium.

Certain unscrupulous persons have profited by man's cupidity and have capitalized fake schemes for extraction of gold and silver from sea water.[9] Blackmore[10] has shown that it is possible to separate some gold from Long Island Sound water, but that the cost is hundreds of times greater than the value of the gold obtained.

The Importance, Properties and Uses of Salt.

Common salt is one of the necessary constituents of man's diet and, consequently, it has been known since prehistoric days. As long as his diet consisted of uncooked food, the fresh meat that he consumed provided a sufficiency of salt; but, when man began to cook his food, the boiling removed a considerable proportion of the salt contained in the meat and it became necessary for him to make up the deficiency. It is not known how long ago man first began using salt from the sea, but the Chinese obtained salt by evaporating sea water before the year 1000 B. C. However, the production of salt from sea water by solar evaporation is a comparatively modern practice.

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[3] *Trans. Roy. Dublin Soc.*, 2d. ser., *7* (1899), 23; and with later corrections *Rept. Brit. Assoc. Adv. Sci.* (1900), 369.

[4] The Data of Geochemistry, 4th ed., *U. S. Geol. Surv. Bull. 695* (1920), 146-151.

[5] *Chem. News, 26* (1872), 159.

[6] *J. Soc. Chem. Ind., 11* (1892), 35.

[7] *Proc. Roy. Soc., N. S. Wales, 29* (1895), 335, 350.

[8] Don, J. R., *Trans. Am. Inst. Mining Eng., 27* (1897), 615.
Wagoner, F. L., *Trans. Am. Inst. Mining Eng., 31* (1901), 807; also idem. *38* (1907), 704.
Pack, J. W., *Mining Sci. Press, 77* (1898), 154.

[9] The Electrolytic Marine Salts Company of Boston, Mass., published two booklets with a view of interesting speculators in their schemes.
"Sketch (A) of the discovery of a commercially profitable process for the extraction of gold and silver from sea water" (1897).
"Gold from sea water at a profit. The facts. Series one and two" (1898).
Curiously enough, Bolton in his section on "Alchemical literature of the Nineteenth Century" in "A select bibliograph of chemistry, 1492-1902" gives these references. Bolton, K. C., *Smithsonian Miscellaneous Collections, 44,* 204-215.

[10] *Cassier's Magazine, 41* (1912), 3-7.

The earliest comprehensive description that we have of the commercial manufacture of salt appears in *De Re Metallica,* a book by the famous writer, Georgius Agricola, of Saxony, which was published in the year 1556. According to the method described by Agricola, sea water was received into long trenches leading to large shallow pits or basins. Fig. 4, taken from *De Re Metallica,* shows the arrangement of the basins. From Agricola's description of the basins, it appears that they were much larger than the drawing would indicate. The sea water underwent a preliminary evaporation in the first series of basins. Then the brine passed into a second series of basins and remained there until the sun and wind had concentrated it considerably. In the third basins, or salt pits, the brine was all "condensed into salt." The salt was raked up with wooden rakes and thrown out with shovels. After the salt had been removed, the basins were filled again and again with sea water.

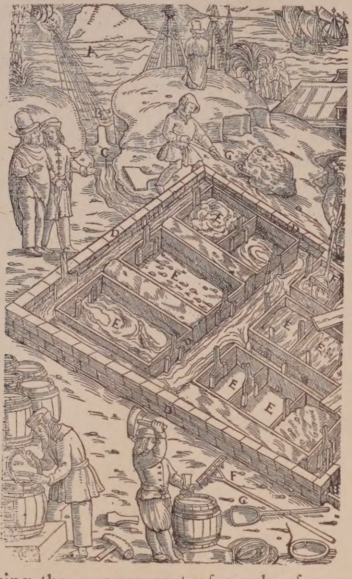

Fig. 4.—Diagram showing the arrangement of ponds of a medieval saline in which salt was prepared from sea water.

Much salt was prepared even in Agricola's time by the artificial evaporation of salt brines and sea water in caldrons. Agricola gives a detailed description of the boiling of brine for salt, which is more explicit than his discussion of the manufacture of solar sea salt.

Such was the very crude process used in Europe during Medieval times. The world's annual production of salt now exceeds eighteen million tons and is increasing with the expansion of the chemical industries. At one time, almost the whole of the salt of commerce was produced by the evaporation of sea water. Now, however, the bulk of the salt is produced either by the mining of rock salt or by the evaporation of brine produced by dissolving rock salt in situ. Nevertheless, the manufacture of solar salt from sea water still is an important industry in many countries. The amount of salt which could be obtained from the sea is tremendous. The average salt content of a gallon of sea water is about 0.2547 pounds of salt, and since the average density of rock salt is 2.24 times that of water, the entire ocean, which has a volume of 302,000,000 cubic miles, if dried up would yield approximately four and a half million cubic miles of salt! In the face of these figures, the beds of rock salt at Stassfurt, and in Ohio, Michigan, New York and Kansas, which seem so enormous, become absolutely trivial.

Common salt is more or less impure sodium chloride. Sodium chloride ($NaCl$) is composed of 39.39 per cent of sodium and 60.61 per cent of chlorine. It is a white lustrous solid which crystallizes in the regular system, generally in cubes. Its solution in water has a bitter brackish taste and is neutral to indicators. Pure sodium chloride is slightly hygroscopic, taking up about one-half per cent of moisture from moist air at ordinary room temperatures. It melts at 772° C., and vaporizes rapidly at white heat. A saturated aqueous sodium chloride solution crystallizes as the hydrate $NaCl.2H_2O$ at $-7°$ C. to $-22°$ C., and at $-23°$ C. $NaCl.10H_2O$ separates.

The solubility of sodium chloride in water at various temperature is given below according to Poggiale:

Temperature	*Sodium Chloride*[11]
—15° C.	32.73
—10	33.49
— 5	34.22
0	35.52
9	35.74
14	35.87
25	36.13
40	36.64
50	36.98
60	37.25
70	37.98
80	38.22
90	38.87
100	39.61
109.7	40.35

Concentrated solutions of sodium chloride possess antiseptic properties, as it extracts water, and therefore salt is used in the preservation of meat, fish and other food products.

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[11] The figures refer to the parts of sodium chloride which will dissolve in 100 parts of water at the temperature given.

As well as for seasoning food and preserving it, salt is used in large quantities in the curing of hides, in the making of brines for use in refrigeration and ice factories, in the making of dyes, in the preparation of sodium and chlorine. Commercially, common salt is the chief source of the sodium of all the sodium compounds except sodium nitrate, which is found in Chile. Metallic sodium is prepared by the electrolysis of molten sodium chloride, chlorine being obtained simultaneously. Practically all of the chlorine of commerce is prepared from salt. A few of the chlorine compounds which are prepared from salt are: sodium hypochlorite, sodium chlorate, sodium perchlorate, bleaching powder, hydrochloric acid and silver chloride. Salt is used in the manufacture of hard soaps. Other industries which use large quantities of salt are: oil refining, the ceramic industries, various metallurgical industries, paper works, and the textile industries.

The German government collects a salt tax on all salt used for cooking purposes; consequently, figures are available which show the amounts of salt used for various purposes. In 1913, the salt used in Germany was distributed as follows:

Food	524,309
Cattle salt	128,800
For soda and sodium sulphate[12]	524,700
For dyes and chemical products	265,660
For tanning	15,257
For salting fresh hides	55,887
For metallurgical uses	35,312
For ceramic industry	11,680
For soap making and oil refining	14,798
For paper works	1,726
For textile industries	9,696
For ice making and cold storage	12,596
For removing ice from tramways	4,426

The nomenclature of the various grades of salt which are obtainable on the market varies in different countries. Domestic American salts are graded as dairy and table salt, which includes table, butter, cheese, pretzel, casing, "paste" and similar special brands. These salts should be very pure salts although they are occasionally adulterated with small amounts of starch or calcium phosphate. According to the standards of the Association of Official Agricultural Chemists: *Table salt* or *dairy salt* is fine-grained crystalline salt containing on a water-free basis not more than 1.4 per cent of calcium sulphate, nor more than 0.5 per cent of calcium and magnesium chloride, nor more than 0.1 per cent of matters insoluble in water.

Packers', common fine and common coarse salt include salt used in curing fish, packing meat, preparing cucumber pickles, curing hides and also salt known as "medium number one" and "ground alum." These salts need not be as pure as dairy salt and the chief differences between these grades as manufactured by the same factory is the difference in the fineness of the crystals. "Coarse solar" is coarse salt manufactured by solar evaporation. Rock salt[18] includes all salt mined and shipped, whether ground, lumped or screened.

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[12] These figures do not include salt used in solution before being crystallized.

Solar Salt.

Importance and Location of Industry.—Although the production of salt by evaporation of brine with artificial heat and the mining of rock salt now greatly exceeds that produced by solar evaporation, the manufacture of salt from sea water by solar evaporation is still an important industry in many warm countries where the annual rainfall is light. In California, more than 97 per cent of the salt produced is made from the solar evaporation of sea water. California ranked fifth among the salt producing states of the United States in 1917, producing 1,536,814 barrels of salt. In Italy, the solar sea salt industry is the major salt industry of the country. Italy produced 397,237 tons of salt in 1916; 330,000 tons of this were sea salt. In 1913, 141,626 tons of sea salt and 32,889 tons of rock salt were exported from France. Spain exports large quantities of sea salt. In Portugal, there are salt works at Aveiro, Figueira, Alcacer do Sal, and Setubal. There are "salzgärten" at various places on the Adriatic Sea including Sabbioncello, Trieste, Pirano and Copo d'Istra. Other countries which possess an important solar sea salt industry include China, Japan, India, Brazil, and many of the islands of the West Indies.

The manufacture of salt from sea water can successfully compete with the production of salt from rock salt only when the industry is located where a cheap source of heat is available, inasmuch as about 90 per cent of the water in the sea water must be evaporated before any crystallization of salt takes place. The only important method of manufacture of salt from sea water, which is utilized on a large scale, is that which utilizes solar heat, consequently the product is called solar salt. In some localities solar sea salt is called bay salt to distinguish it from solar, artificial brine salt, which is also called solar salt. Inasmuch as rapid evaporation of the water is necessary, the solar sea salt industry has thrived only along the seacoast of countries which possess a dry climate or have hot summers.

Moreover, in order to establish a successful salt works, a large acreage of level land adjoining a bay or the ocean is required. The ground underlying the site of the salt works must be nearly impervious to water. Soils which are most satisfactory are clays and clayey marls. If the ground is "leaky," it must be puddled with clay before it can be used. This is very important, as leaks in the bottom of salt ponds are very difficult to stop and cause unnecessary dilution of the brine and reduce the yield of salt.

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[18] It is customary to grade domestic salt in the following manner: Grade No. 1 consists of grains about the size of grains of wheat. Grade No. 2, of which most is manufactured, is composed of cubes about one-eighth to one-quarter inch in diameter and is used by the packers for making brines and for salting hides. Grade No. 3 is coarse, the grains being from one-fourth to three-eighths inch in diameter, and is used largely in refrigerator cars. Grade No. 4 is about as fine as coarse evaporated salt and it is used by stockmen, soap makers, glass manufacturers and also in chlorination furnaces. Grade "Common Fine" or "C.F." contains all grades from No. 1 to the coarsest. "Packers' fine" is the finest grade made and is used for domestic purposes and also for packing beef and pork. Lump salt is obtainable at all the mines and consists of very large lumps, usually weighing many pounds. Lump salt is sold for salting live stock.

It is impractical, for obvious reasons, to discuss all the commercial methods of manufacture of salt from sea water in a work of this nature. There are five chief types of processes of manufacturing salt from sea water in commercial use to-day, viz.: (1) The oriental leaching process. (2) The oriental solar process in which no attempt is made to separate impurities from the salt. (3) The improved oriental solar process in which sediment, calcium carbonate, iron oxide, and calcium sulphate are separated by preliminary evaporation of the sea water in concentration ponds. (4) The European solar process in which the sediment, iron sulphide, calcium carbonate and calcium sulphate are separated from the brine by preliminary evaporation of the sea water and in which the greater proportion of the chlorides of calcium and magnesium are removed by withdrawing the mother liquor from the crystallizing ponds when these salts begin to separate. (5) The Norwegian process in which sea water is concentrated by freezing and subsequent removal of the ice. After concentration the salt is recovered by the evaporation of the concentrated brine.

In addition to the sea salt made by the five types of processes mentioned above, a small amount is made in isolated places by the simple evaporation of sea water in pans by means of artificial heat.[14] Some salt is obtained annually from the evaporation of sea water in natural lagoons which occur on some of the islands of the West Indies and in Mexico, China and elsewhere.

In the oriental leaching process and in the oriental solar process, no attempt is made to separate the sodium chloride from the other salts contained in sea salt; consequently these salts contain relatively large amounts of calcium, magnesium and iron salts and are usually dark in color. The salt prepared by the improved oriental process usually contains less clay, calcium carbonate and sulphate, and iron oxide than that produced by the ancient oriental process, since these substances are removed in the concentration ponds where the brine undergoes a preliminary concentration previous to its transfer to the crystallizing ponds.

The European salt trade demands a white salt, and, therefore, more pains are taken to separate the sand and clay from the salt. Moreover. the European salt-makers attempt to separate the calcium and magnesium salts by preliminary evaporation to a density of about 25° Be. (1.196 sp. gr.) before the brine is run into the crystallizing ponds, and by removing the bittern or mother liquor when it begins to separate salts other than sodium chloride. The European solar salt, however, is "wet" as the separation of the calcium and magnesium chlorides is imperfect and these salts impart hygroscopic properties to the salt.

The process of manufacturing salt which is employed in California is a modification of the European solar process. The California salt producers have learned that dry salt brings a higher price in America than wet salt, therefore they are careful to see that their salt contains only traces of calcium and magnesium chlorides and sulphates. This is accomplished by drawing off the bittern at a relatively low density. Thus they obtain a slightly smaller yield of salt but produce nearly pure sodium chloride. Table 2 gives analyses of solar sea salts manufactured in various parts of the world.

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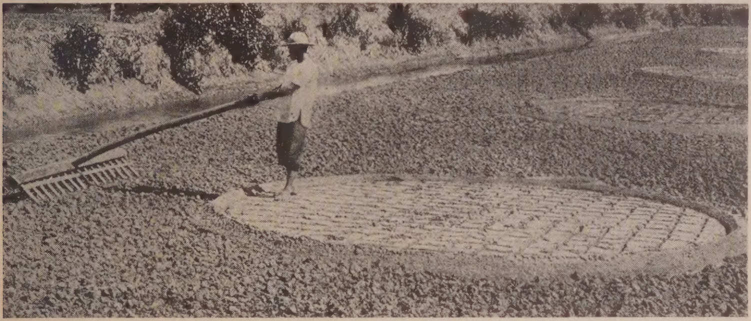
[14] In Burma, a relatively large amount of sea salt is produced by the artificial evaporation of sea water. (*Rangoon Gazette*, Nov. 11, 1918.)

The various processes for the manufacture of salt are described below. Since the California processes produce the purest salt, and represent the best commercial practice, these methods will be considered in greater detail than the others.

The Oriental Leaching Method.—Much of the salt produced in the orient to-day, is obtained by methods which are extremely crude, whose origin dates back to prehistoric times. These simple methods are only of historical interest and so will be described briefly here. Cox and Juan[15] studied the native methods of salt manufacture of the Philippines and have described them as follows:



Courtesy Philippine Bureau of Science.

FIG. 5.—Salt production by the Filipino method. Preparing the soil to be sprinkled with sea water. Bacoor, Cavite Prov., P. I.

> "Large areas of sandy land along the coast, approximately at the level of high tide, are cleared of vegetation and cleaned. The surface of the prepared land (*abuhan*) is loosened, and water from canals (*angkaw*), through which it is led in from the sea or *estero,* is sprinkled over the area where it rapidly evaporates. This process is repeated about four times a day for three consecutive days, until a quantity of salt has accumulated on the surface. On the fourth or the fifth day the loose earth, together with the salt, is scraped into heaps and collected into leaching vats called *hornohan* (from the Spanish 'horno' which literally means 'oven'), where it is leached with sea water or weak brine until most of the salt has been extracted, and a concentration of about 10 per cent of salt by weight is obtained. In many plants using the Filipino method the leaching vats are located at a point intermediate between the canals where the sea water is available. In this case the sea water is conveyed to the vats by an inclined bamboo pipe, the lower end of which rests upon an open-work bamboo basket, or other device, to prevent violent impact of the water, and the upper and larger end of which carries an earthenware jar (*pilon*) or galvanized-iron funnel to receive the water.
>
> "In the Philippines, there are many salt-water shrubs and trees which when

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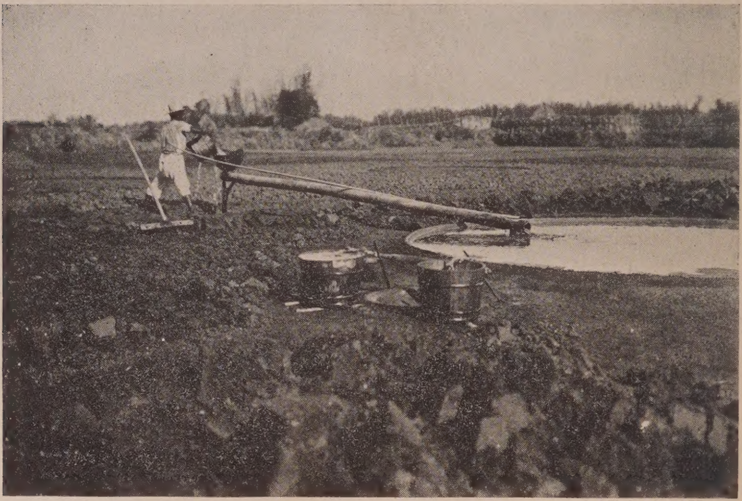
[15] "Salt industry and resources of the Philippine Islands." *Philippine J. Sci. 10* (1915), Sec. A, 375-401.

green have a specific gravity greater than that of water. In Rizal, Cavite and Bulacan Provinces it is a common practice to pluck twigs of the plant known by the name of *culase* (*Lumnitzera racemosa* Willd), which grows in the marshes near salt farms and along the levees of the evaporation reservoirs, strip them of their leaves, and throw them in the brine to test its strength. If they sink, the brine is not yet strong enough, but when they float, the brine is sufficiently concentrated to be transferred to the crystallizing ponds, called *banigan*. The specific gravity of the culase twigs of the size used has been determined by one of us to be about 1.085, or equivalent to 11.5 per cent by weight of salt. The culase varies from 1.070 to 1.096, depending on whether it is smaller or larger than the size used by the Filipinos in determining the strength of the brine. There are very few Filipinos who use a specific gravity spindle or a salimeter to determine the strength of the brine.



Courtesy Philippine Bureau of Science.

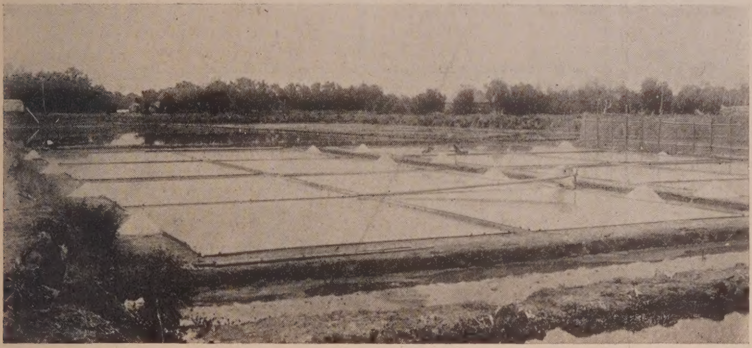
FIG. 6.—Leaching prepared soil with sea water. Bacoor, Cavite Prov., P. I.

"The leaching vat commonly used in Rizal and Cavite Provinces consists of a circular dike about 50 centimeters high and 4 meters in diameter, which is built on the ground. The bottom is covered with a layer of palm leaves, usually nipa, and rice husks, which filter the mud from the brine. By means of bamboo piping the filtered brine is drawn off through a dike into a shallow cement, earthenware (*pilon*), or clay-lined well. Dilute brine is dipped back into a leach, and the operation is repeated, until it becomes strong, when it is transferred to shallow crystallizing ponds.

"After the leached mud has hardened slightly, it is marked off into squares. While the leaching is in progress, another layer of loose earth is being impregnated. This is scraped into heaps about the leach, while the squares of leached mud are drying. When the blocks have sufficiently hardened, they are thrown from the leach back on to the field. After the second crop of salty earth has been scraped into the leach, the clods are pulverized and carefully spread out again to be impregnated.

"The crystallizing ponds are floored with smooth broken pottery (*tinajas* or *pilones*) set in lime mortar to retard seepage and to prevent the admixture of sand with salt. The ponds are surrounded with bamboo fences covered with nipa or cogon grass in order to prevent the prevailing wind from blowing dust into them and the floating crystals from congregating on the leeward side. As the crystallizing ponds require more liquid, more and more of the strongest brine is added. It is poured through a straw-filled, open-work basket filter to remove rice husks, which may have gotten in from the leach, and especially to prevent disturbance of the bottom of the pond. When the brine is sufficiently concentrated to deposit salt, every day after sundown, when the temperature has fallen, to give the maximum crystallization, the crystals are raked into heaps at the side of the vats, gathered into baskets to drain, and finally conveyed into warehouses."

Such is the simple, picturesque method used by the native Filipinos in making salt. In some parts of the Philippine Islands, in some sections of China, and in Japan, the process described above is modified by evaporating the leachings in pans or kettles over fires built in furnaces.



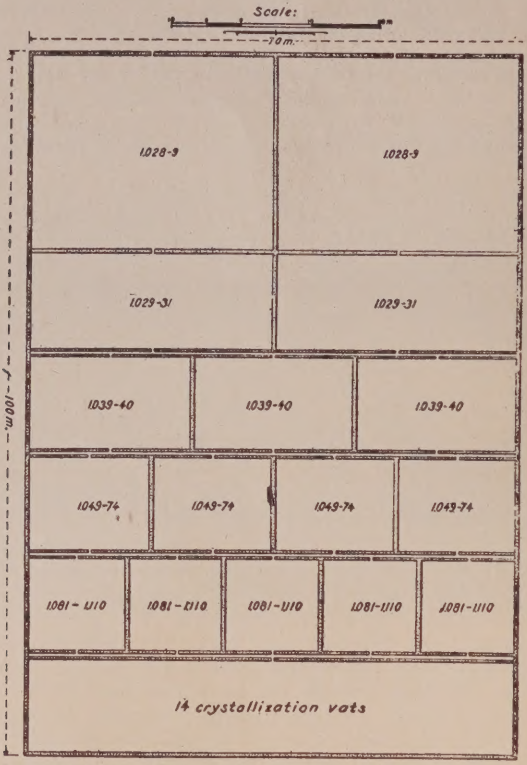
Courtesy Philippine Bureau of Science.

FIG. 7.—Crystallization ponds where brine obtained by leaching is evaporated and the salt crystallized. Malabon, Rizal Prov., P. I.

The Oriental Solar Process.—In China, the simplest possible process of manufacture of solar salt is employed in the making of much of the sea salt. The identical methods are known to have been in use for a thousand years or more. In fact, there is no record to show just when the salines were established. The salt is made by the solar evaporation of sea water without any attempt at the separation of the impurities from the sodium chloride. The process is essentially as described below.

Sea water is pumped into large evaporating basins by means of windmills. These basins are constructed on the flats along the seacoast and resemble innumerable tennis courts of great size. The basins are constructed by leveling the ground and then rolling it hard with a stone roller. The basins are separated from each other by low ridges of mud about eight inches high. They are arranged in groups so that they may be filled with a central pump. About three inches of sea water is pumped into the pond, which evaporates to dryness in about a week, leaving a coating of salt on the bottom. This salt is scraped into a pile and then shoveled into small boats. The bottom of the basin is then rolled again and more sea water is pumped in and the salt making continued. The ponds are connected by means of small canals to the main salt yards which are near either a railroad or a river. The salt is stored at the salt yards in great heaps which usually are covered with mats.

The Improved Oriental Process.—In some sections of China, Japan, and the Philippines, solar sea salt is produced by a process resembling the

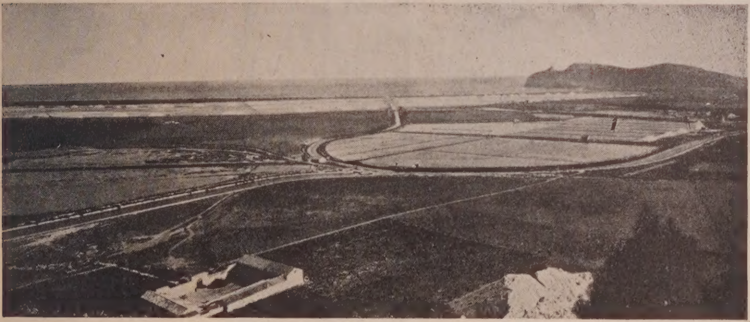


Courtesy Philippine Bureau of Science.

Fig. 8.—Diagram showing arrangement of the ponds of an improved Oriental saline.

European solar process inasmuch as the sea water is first allowed to settle and concentrate in concentration ponds until it is nearly saturated and is then run into crystallizing ponds where the salt is allowed to crystallize from the brine. The preliminary evaporation which takes place in the crystallizing ponds permits the sediment to settle and also causes the precipitation of the iron sulphide, calcium carbonate and most of the calcium sulphate. Since the concentrated brine is allowed to evaporate to complete dryness, the salt produced by this method is high in calcium and magnesium chlorides.

The arrangement of the ponds is shown in Figure 8. The reservoir in which the preliminary evaporation takes place is usually a fish pond; and in addition to this, in most salt plants, there are three rows of shallow concentration reservoirs. The brine is run from one reservoir to another as its density increases and more sea water is admitted into the fish pond to replace that lost from the ponds by evaporation. Beyond the reservoirs, crystallizing ponds are constructed to which the brine is transferred when it attains a density of approximately 1.13. Because of the low density at which the brine enters the crystallizing ponds, the salt made by this process contains a relatively high amount of calcium sulphate[16] as well as large amounts of other calcium and magnesium salts which crystallize when the mother liquor approaches dryness.



Courtesy National Geographic Society. Copyright, 1923.

Fig. 9.—Italy's most important salt works, on the flats south of Cagliari. Here the great piles of salt are handled by steam shovels.

The European Solar Salt Process.—The greater proportion of the world's production of sea salt is manufactured by the European solar process. Practically all of the sea salt produced in Europe, the West Indies, South America and Africa is made in this manner. This process is a decided improvement on the ancient oriental solar process and the product contains less impurities. The chief countries of Europe which produce solar sea salt are France, Spain, Portugal and Italy The customary procedure followed in manufacturing salt by this method is described below.

The salines or salt farms are laid out on low-lying flat land adjoining a bay or the ocean. The flats are enclosed by high dykes to prevent flooding from high sea or storms. Each "salt meadow" is subdivided into compartments of different levels by internal walls as shown in the diagram (Fig. 10). One end of the salt farm is usually slightly higher than the other in order that the brine may flow from one compartment to another by gravity. When the dry season begins, sea water is either pumped or admitted through a canal at high tide into the higher compartment (A) and is allowed to stand in the concentration pond until the clay and other suspended matter settle. A preliminary evaporation takes place during the clarification. Next, the concentrated, clarified sea water is run out into shallow reservoirs (B) where it remains until it reaches 23-25° Be. (1.178-1.196 sp. gr.). By the time the brine has reached this density, the iron sulphide and calcium carbonate have precipitated out and most of the calcium sulphate has been thrown down. Then the nearly saturated brine passes into a second series of shallow reservoirs (C). The rate of flow of the brine is regulated so that by the time the brine reaches the last row of these compartments, salt has begun to crystallize out.[17] The evaporation in reservoirs (C) is allowed to proceed until the brine reaches a concentration of about 27° Be. (1.229 sp. gr.). The saturated brine is then run through the canal (D) into the crystallizing ponds (E), where the crystallization of the salt takes place more or less rapidly depending upon

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[16] In the European and California processes, the brine is not transferred to the crystallizing ponds until it reaches a density of at least 1.187 (24° Be.) by which time all of the calcium sulphate has been precipitated.

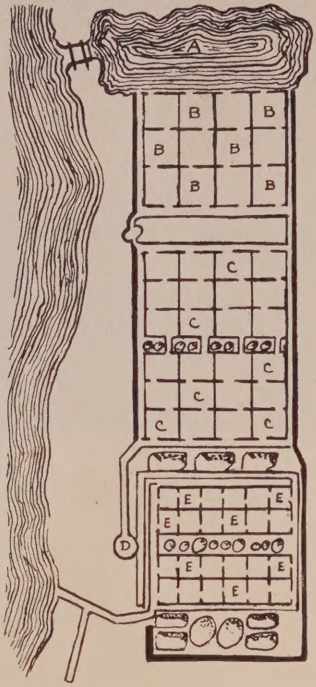

FIG. 10.—Diagram showing the arrangement of ponds in a typical European saline.

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[17] Salt begins to crystallize rapidly at about 25.2° Be. (1.2104 sp. gr.).

the rate of evaporation. The evaporation is continued usually until the mother liquor reaches a density of 32° Be. (1.2830 sp. gr.). If the crystallization of salt is continued beyond this point, salt containing large amounts of calcium and magnesium chlorides is obtained. The bittern is then run off into bittern ponds. In the Giraud district in France, the mother liquors are worked up into magnesium and potassium salts according to a process introduced by Balard which is described in the following chapter. After the bittern is run off, the salt remaining is broken up and raked together and hauled to the salt yards where it is piled in large heaps in the open air where it slowly dries. The occasional showers purify it somewhat, for the rain dissolves the more soluble calcium and magnesium chlorides.

The salt produced in this manner contains from 95 to 97 per cent of sodium chloride. The impurities are chiefly calcium and magnesium chlorides and sulphates as is shown by the analyses given in Table 2 on page 48. This salt is hygroscopic because of its high calcium and magnesium chloride content. It is highly prized for salting fish and hides. It is particularly desirable for salting hides where they are sold by weight as the salted hides do not have a tendency to dry out and consequently do not lose weight.

Photo by W. W. Browne.

FIG. 11.—Raking salt in saline at Turk's Islands.

The California Solar Salt Industry.—The solar salt industry has been particularly successful along the California coast, inasmuch as the rainfall during the salt-making season is very slight. The largest plants are located near San Francisco in Alameda and San Mateo Counties. The other plants are located in the southern part of that state, one being at Ostend Station near Long Beach and the other on San Diego Bay, San Diego County. The general method of production of solar salt is nearly the same in all these places although the various operations differ considerably in details.

The salt-making process as it is carried out in the plant of the Western Salt Company at the southern end of San Diego Bay has been described by Palmer[18] and Mason,[19] and is typical of present day practice in

[18] *Met and Chem. Eng. 16* (1917), 317-319.

[19] *Min. and Sci. Press, 118* (1919), 528-530.

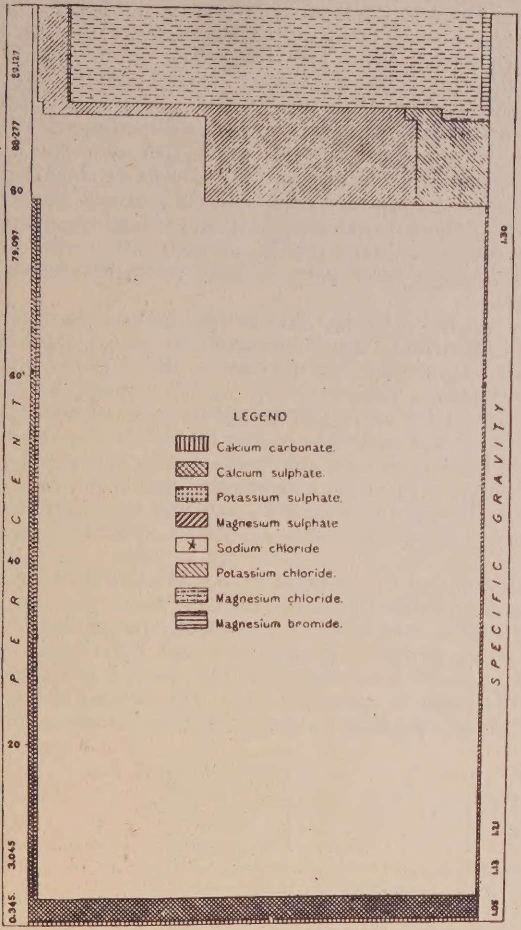
California in the manufacture of high grade salt by solar evaporation. San Diego Bay which is the source of supply of sea water is a long and narrow arm of the Pacific Ocean. The inflow of fresh water is very slight, and, consequently, the salt content of the water at the southern end of the Bay where the plant is situated is somewhat higher than that of ocean water. According to Palmer, samples of the water of San Diego Bay have occasionally run as high as 5 per cent of sodium chloride. The net annual evaporation of San Diego Bay is 50 inches, a total evaporation of 60 inches against an average precipitation of 10 inches.

At high tide, bay water is admitted into the four tide ponds through tide gates which have a total area of 250 acres. The ponds are surrounded by a levee about 10.5 feet high and three miles long. The water is retained in the tide ponds for two weeks and then pumped, by means of two centrifugal pumps which have a combined capacity of 15,000 gallons per minute, into secondary ponds. Each pump has a 36 inch suction and a 24 inch discharge, the two discharge pipes uniting in one main 36 inch line. By this means, the water is lifted eight feet to a sump, from which it flows to the high point of the secondary ponds, among which it is distributed by means of gates between the ponds. This plant has nine secondary ponds which have a total area of 333 acres. By the time another flow of brine from the tide ponds is due (about two weeks), the water in the upper ponds has reached a density of about 6.77° Be. (1.041 sp. gr.) and is run into the lower secondary ponds to make room for another run. The lower secondary ponds are sometimes referred to as "lime ponds" as the calcium carbonate precipitates and settles to the bottom of the pond at a brine density of about 7.82° Be. (1.057 sp. gr.). The evaporation is continued in the lower secondary ponds until a density of 9.26° Be. (1.0682 sp. gr.) is reached. From the last to the secondary ponds, the brine is run to the pickling pond, which has an area of 112 acres. In this pond, the evaporation is continued until the brine has a density of 24.1° Be. (1.193 sp. gr.). At 13.78° Be. (1.095 sp. gr.), calcium sulphate begins to settle out and is practically all thrown down by the time the density reaches 1.193 sp. gr. When this density is reached the brine is run into the crystallizing pond of 51 acres and at 25.2° Be. (1.2104) salt begins to crystallize.

The density of the brine in the crystallizing ponds is such that one inch of salt is thrown down for each six to seven inches of annual evaporation of water, so that the annual deposit of salt is from seven to eight inches. As the weight of one acre inch of salt is approximately 110 tons, this gives a "crop" of 770 to 880 tons per acre. The most economical harvesting of salt is obtained when the depth of the salt is about eight inches.

When the density of the brine in the ponds reaches 29.67° Be. (1.2574 sp. gr.), the mother liquor is transferred to the bittern ponds. The sodium chloride will crystallize out in a nearly pure form with the exception of a small amount of magnesium chloride up to a density of 30° Be. (1.2609 sp. gr.); but above this density, other salts are deposited, magnesium sulphate being the first to be thrown down.

"Harvesting" usually begins the latter part of August and continues until the latter part of November. The crystallized salt is broken with pickax and then shoveled by hand into small two way dump cars on 36 inch tracks, which can be shifted from time to time to keep them within reach of the shovelers. A small gasoline "locomotive" hauls the loaded cars out of the crystallizing pond and the salt is dumped into a V-shaped bin about 100 feet long, 4 feet wide, and 4 feet deep. Its sides are sloping and it is provided with rack and pinion gates in the bottom which are operated from above by hand wheels. In this manner, the salt is discharged through the bottom to a screw conveyor, which works it to a belt elevator. This



Courtesy Philippine Bureau of Science.

FIG. 12.—Diagram indicating deposition of salt from sea water.

elevator dumps the salt into the "washer," which is simply a trough 2 feet wide, 4 feet deep, and 30 feet long, with a screw conveyor in the bottom. The salt is washed by working it through the trough against a current of brine from the "pickling" pond (density about 12.5° Be., 1.0944 sp. gr.). The brine flows back to the pond after passing through the trough.

The screw conveyor from the washer delivers the salt to a bucket elevator which lifts it about fifty feet. The salt receives a final brine washing at the bottom of the bucket elevator and as it is elevated it passes under a spray of fresh water. This removes any dirt or mother liquor that may have escaped the previous washings. According to Palmer "the dried product analyses 99.823 per cent NaCl. The small amount of impurities which does remain consists of sulphates of calcium, magnesium, and sodium, and chlorides of calcium and magnesium." The bucket elevator dumps it into another trough containing a screw conveyor which works the salt out on a trestle. Bottom gates in this trough permit its discharge at any desired point to large stock piles which are usually fifty feet high.

After the salt has dried to 1.5 to 2.0 per cent of moisture, it is sacked when needed. Horizontal screw conveyors are placed under the platforms supporting the "stock piles," so that, as the salt is picked down by workmen, it is carried to a scraper elevator which delivers the salt to a short screw, which feeds a 4 by 12 feet hexagonal trommel with a ⅜ inch wire screen. Oversize and undersize of the trommel run to spouts and then into 50 pound sacks, which are automatically weighed, sewed and tossed to a short belt conveyor by which they are delivered to the shipping platform. The elevating, sacking, and weighing machinery are mounted on trucks on a track running parallel to the stock pile, so that they may always be convenient.

The annual output of the plant of the Western Salt Company which has been described is from 30,000 to 40,000 tons.

The salt-making operations of the plants around San Francisco Bay are conducted in a similar manner although differing in some details. Evaporation proceeds more slowly in this district and consequently the annual yield per acre is somewhat less. The rainfall and evaporation in inches during the salt-making season at San Francisco Bay are given below:

Month	*Rainfall*	*Evaporation*
April	1.36 in.	3.38 in.
May	1.14	5.31
June	0.67	6.62
July	0.00	7.81
August	0.00	7.81
September	0.00	4.94
October	0.77	2.94

As in the San Diego district, the bay water is not taken into the works continuously but only at the times when the tides are highest.

The salt content of San Francisco Bay is lower than that of San Diego Bay. Comparative statistics are given by Phalen.[20]

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[20] *Bureau of Mines, Bull. 146* (1917), 42.

DENSITY AND SALINITY OF SEA WATER USED IN SALT MAKING (CAL.)

Source	Date of Collection	Density	Specific Gravity[21]	Percentage of Salt[22]
	1912	° Be.		
San Francisco Bay at Mount Eden	Oct. 5	3.53	1.025	3.44
San Francisco Bay at Alvarado...	8	3.12	1.022	3.34
San Diego Bay	17	4.10	1.029	4.00
Sea water	....	....	1.027	3.72

Although the water of San Francisco Bay contains less salt than the ocean, all but two of the salt works of California are situated on the Bay; for a large area of level clay marl, which is nearly impermeable to water, lies in close proximity to the Bay. This permits the making of solar salt in ponds without danger of dilution through leaks in the bottom of the ponds.

The larger salt works in this vicinity cover 1,800 acres, of which about 75 acres are used as crystallizing ponds and the remainder are used as concentration ponds. The average annual yield of salt from a plant of this size is 25,000 tons.

Procedure at San Francisco Bay.—At high tide, bay water is admitted through a gate into the main canal. Archimedean screws propelled by windmills, centrifugal pumps operated by gasoline engines or electrically driven water-wheels pump the water into the settling ponds. These ponds are at least eighteen inches deep. Here the suspended matter contained in the sea water settles to the bottom and the preliminary evaporation takes place. In the first settling ponds, silica, alumina and iron sulphide precipitate out, and in the secondary or lime ponds, calcium carbonate and more iron sulphide come down. Walls built within the ponds make the brine circulate as it passes through the reservoirs. In the settling ponds, a lively growth of green algæ, brown algæ, diatomaceæ and a very active bacterial growth are found. Larvæ of the marsh fly and other insects are numerous in these ponds; and in the ponds containing nearly saturated brine, "brine-worms" (a small crustacean *Artemia salina*) are found in enormous numbers.

The brine passes from the settling ponds to the so-called pickling ponds, in which most of the calcium sulphate separates in these ponds in brown, green or yellow crystalline concrements. In addition to calcium sulphate, iron sulphide is found in the sediment in the pickling ponds; this sulphide probably is formed by the reduction of the sulphates by the organic matter. The brine remains in the pickling ponds until it reaches a specific gravity of 1.198 to 1.2085 (97-101.5° Sal.).[23] By this time, practically all of the gypsum has been deposited. Even at 1.194 sp. gr. (95° Sal.), there is no danger of deposition of gypsum on the salt-

[21] Specific gravities were taken at 22° C., but are referred to water at 15° C.

[22] Assumed to be pure NaCl, which is not exactly correct.

[23] °Sal. refers to the salimeter scale obtained by the use of a special hydrometer that is marked 0° at the point which it sinks in water at 60° F. and 100° at the point which it sinks in saturated sodium chloride solution at the same temperature.

crystals in the crystallization ponds [24]; but for safety's sake and especially on account of irregularities in the density of the brine, which varies at times even within the same pond, brine of lower density than 1.198 sp. gr. (97° Sal.) is never used in the crystallizing ponds.

As the concentration of the brine approaches saturation, the brine-worms and algæ die and the solution becomes pinkish in color, because of the growth of certain red and pink bacteria. The salt-maker takes this change of color as an indication that the brine is ready to be transferred to the crystallization ponds.

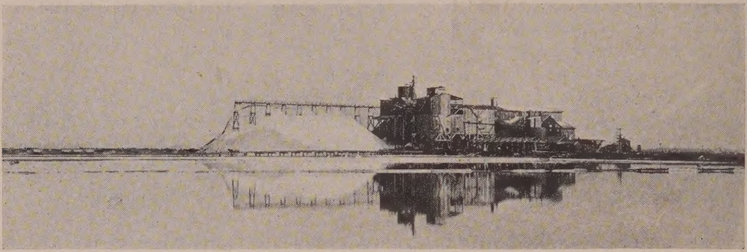

FIG. 13.—General view Continental Salt and Chemical Company's saline and refinery.

From the liming ponds, the brine, or pickle as it is sometimes called, passes to the crystallization ponds where crystallization of salt begins at a density of 1.2104 sp. gr. When the ponds are filled to a depth of ten or more inches, large salt crystals are usually obtained. However, the temperature of the brine and the rate of evaporation also affect the size of the crystals. Cold weather causes small hard crystals to be formed. Hot weather and a low brine stratum during crystallization result in the formation of soft crystals.

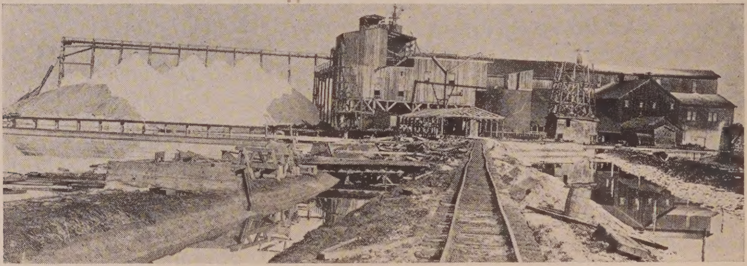

FIG. 14.—Continental Salt and Chemical Company's plant at San Francisco Bay, one of the largest solar salt works on the Pacific Coast.

As more and more of the salt crystallizes from the solution, the magnesium and calcium chloride content of the mother liquor increases; this causes the mother liquor to become oily in appearance. The greater proportion of the salt crystallizes from the solution between the densities 1.2185 sp. gr. (26° Be.) and 1.2341 sp. gr. (27.5° Be.).

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[24] Unpublished data obtained by Carl Elschner.

It requires some skill for the salt-maker to regulate the requirements of the crystallizing ponds so that there will be always enough of the saturated brine from the last concentration ponds (pickling ponds) on hand. If there is an over supply of the saturated brine in the pickling ponds, the mother liquor is drawn off at 1.2394 sp. gr. (28° Be.). Otherwise the brine is allowed to remain in the crystallization ponds until it reaches a density of 1.2500 sp. gr. (29° Be.) as some salt continues to crystallize. If the brine is permitted to evaporate at higher densities, the salt which crystallizes becomes more and more impure and a film of salt begins to cover the greater part of the pond. The mother liquor which is drawn off from the crystallizers is called bittern. The salt manufacturers utilize the bittern for making various by-products; these processes are described in the following chapter.

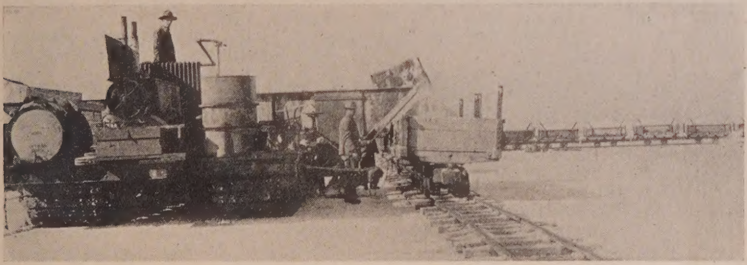

Fig. 15.—Salt harvesting machine used by the Continental Salt and Chemical Company.

The crystallization ponds are filled two to five times each season. The brine is run in on the previous crystallizations, for the salt is not harvested until the end of the season. In this region, the salt is removed from the crystallizers before the December rains begin.

In the smaller salines, the salt is harvested with picks and shovels and is hauled to the piles in wheelbarrows. The larger and more up-to-date plants use small dump cars, running on movable rails and hauled by gasoline locomotives, for transporting the salt to the washing machine. The removal or "lifting" of the salt with pick and shovel is quite efficient in one regard for it is possible to remove practically all of the salt from the beds without disturbing the bottom and thus contaminating the salt with earth. An efficient mechanical lifter (Fig. 15) has been perfected by the Continental Salt and Chemical Company. A horizontal scraper is mounted on a large caterpillar truck. As the truck slowly moves along, the scraper takes up the salt and throws it on a conveyor which empties it into the dumping cars. This mechanical lifter can turn in any direction.

When the salt is removed from the beds it is often dark-colored, because of admixed iron sulphide, organic matter, etc., and occasionally it contains red, yellow and brown streaks. However, with careful washing, these discolorations may be removed. The procedure followed and the equipment used in washing the salt is the same as in southern California, which has been described heretofore. The washed salt is dumped on huge heaps exposed to the weather. The rains help to purify the salt by washing away the mother liquor. The drainage from the salt piles runs back into the ponds.

Before the salt is sold, it is crushed, screened and sacked.

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Chapter 3.

The Refining of Sea Salt and the Recovery of By-Products from Bittern.

*By Donald K. Tressler, Carl Elschner and George B. Willcox**

The Necessity of Refining Sea Salt.

The characteristic properties of the various grades of commercial sea salt to a large extent are imparted by its impurities and the shape and size of the individual crystals. The taste, color, odor, and hygroscopicity of commercial salts are controlled by the nature and amount of substances other than sodium chloride in the salts. Sodium chloride has a brackish taste but is not bitter; whereas calcium and magnesium salts are very bitter. Consequently, the higher the content of calcium and magnesium salts in common salt, the more bitter is its taste. Iron, organic matter, and bacteria cause salt to be colored. Most sea salt contains relatively high numbers of red bacteria which often give it a pink tinge. Organic matter and iron salts darken sea salt. Organic matter of marine origin give sea salts peculiar odors often described as the "smell of the sea." Pure sodium chloride is only very slightly hygroscopic whereas calcium and magnesium chlorides are highly hygroscopic; therefore the presence of but small amounts of calcium and magnesium salts make sea salt hygroscopic.

For many purposes, such as for table, dairy and chemical uses, nearly pure salt is required. For this reason, pure salt brings a higher price than crude salt. Since it is difficult to produce high grade salt by the solar process, the most up-to-date salt works, that desire to market their salt in the most valuable form, refine the low grade salt by various processes which are considered in this chapter.

Little sea salt is refined in Europe, since most of the salt refineries are located in Great Britain, Austria and Germany where the salt refined is that obtained either from mines or wells.

The American sea salt refining industry is located in the vicinity of San Francisco Bay, California, the center of the solar sea salt industry. Four salt works operate very large refineries in that locality.

The composition of solar sea salts from various parts of the world is given in Table 2.

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* President, Willcox Engineering Company, Saginaw, Michigan.

TABLE 2

ANALYSES OF SAMPLES OF SEA SALT[a]

(Per cent on moisture-free basis)

	Domestic Salts	Imported Salts			
				Bahama Islands	
	California: 23606-H, Leslie bulk salt from barrels, Leslie Salt Refining Co.	France: P-7917, Bonaire Salt Exp. Co.	Spain: P-8657, Pela Emprexado Navagaçoa, Lisbon.	P-7853, D. F. & H. F. Harriott, Turks Island.	B-9015-16, Alfred Slotts Estate, Turks Island.
Radicals	Per cent	Per cent	Per cent	Per cent	Per cent
Arsenate (AsO_4)	....	....	None	None	....
Tetraborate (B_4O_7)	None	?	Trace	None	Trace
Sulphate (SO_4)	0.021	1.692	1.727	1.72	0.403
Carbonate (CO_3)	....	....	.000	....	....
Bicarbonate (HCO_3)	....	....	.013	....	....
Chloride (Cl)	60.70	58.51	59.34	59.44	60.16
Iron (Fe)	....	....	....	....	....
Calcium (Ca)	.025	.764	.471	.45	.167
Strontium (Sr)	....	....	.008	....	....
Barium (Ba)	....	....	....	....	....
Magnesium (Mg)	.000	.090	.396	.47	.022
Sodium (Na, calculated)	39.34	37.71	38.02	37.97	38.98
Silica sand, etc. (SiO_2)	.008	1.312	.086	.13	.293
Total	100.09	100.08	100.06	100.18	100.03
Combinations					
Sodium chloride (NaCl)	100.01	95.86	96.63	96.52	99.09
Sodium bicarbonate ($NaHCO_3$)	....	....	.018	....	....
Magnesium chloride ($MgCl_2$)	....	.35	.967	1.20	.08
Magnesium sulphate ($MgSO_4$)	....	....	.737	.80	....
Calcium chloride ($CaCl_2$)	.045	.16	....	....	....
Calcium sulphate ($CaSO_4$)	.030	2.40	1.602	1.53	.57
Strontium chloride ($SrCl_2$)	....	....	....	....	....
Strontium sulphate ($SrSO_4$)	....	....	.017	....	....
Barium chloride ($BaCl_2$)	....	....	....	....	....
Ferric oxide (Fe_2O_3)	....	....	....	....	....
Silica sand, etc. (SiO_2)	.008	1.312	.086	.13	.293
Total	100.09	100.08	100.06	100.18	100.03
Moisture	.159	1.39	4.475	4.19	.31
Remarks	Fine crystals	Coarse crystals	Coarse crystals	Coarse crystals	Large crystalline lumps

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[a] From Tressler, D. K., *Bureau Fisheries, Doc. 884* (1920).

American Processes of Refining Sea Salt.

Principles and Methods.

Sea salt is refined either by rewashing, grinding, and screening the crude salt or by dissolving and recrystallizing either in grainers or vacuum pans.

A clear understanding of the mechanical principles of salt crystal formation is necessary for a scientific study of salt refining. Salt crystals have their beginning at the brine surface. Vapor rises from the heated brine and tiny specks begin to appear at the surface. The individual "seed crystals" enlarge rapidly, the rate of growth depending upon the rate of evaporation and the heat supplied. Undisturbed, the salt particle enlarges to a small cube, that by its weight indents the liquid surface like a small weight hung on the under side of a thin sheet of rubber. A transparent four-sided fence-like rib of crystal forms around the four top edges of the little cube, caused by evaporation from the four sloping brine filaments. The result is a delicate and very small dish-like structure of salt with the original cube at its bottom. The cube enlarges, becomes heavier and finally by its weight settles slightly, although still prevented from sinking by surface tension.

A second fence-like crystalline rib forms in this newly depressed area, surrounding the first rib, thus enlarging the four-sided crystal dish. Again and again, the processes of taking on weight, settling slightly and forming another addition to the rim of the dish are repeated until finally there floats on the surface a most beautiful hopper-shaped structure. Taken from the liquid and dried on a piece of blotting paper, the hopper crystal, which, if carefully made, may be half an inch or more across and a quarter inch deep, is seen to consist of a relatively large cubical crystal at the apex and four outwardly flaring delicately ribbed thin shell-like flake walls. The corner "seams" are observed to be built up of a number of smaller cubical pieces arranged like the steps of an Egyptian pyramid, as shown in Fig. 16.

The slower the evaporation the greater will be the proportion of "flake" to "cube" in any one hopper. When first formed, the hoppers are very thin and fragile, but, if allowed to remain undisturbed on the brine surface, the apex cube and the corner cubes, or steps, enlarge, the fragile walls increase in thickness, and finally the hopper dips, fills with brine and slowly sinks to the bottom.

Not all of the original salt crystals develop into perfectly formed individual hoppers. The new-formed particles exhibit strong affinity for each other and at every opportunity gravitate together, sometimes forming a thin flat mat composed of little cubes and flakes (Fig. 16). Sometimes several partly grown hoppers draw together and unite at their edges to form multiple hoppers (Fig. 16).

If evaporation is allowed to proceed still more slowly, and the brine surface is not agitated, as in well protected solar ponds or in coarse salt grainers, the hoppers grow much larger and thicker before sinking (Fig. 16).

After a hopper of large size sinks, it in time fills with small hoppers

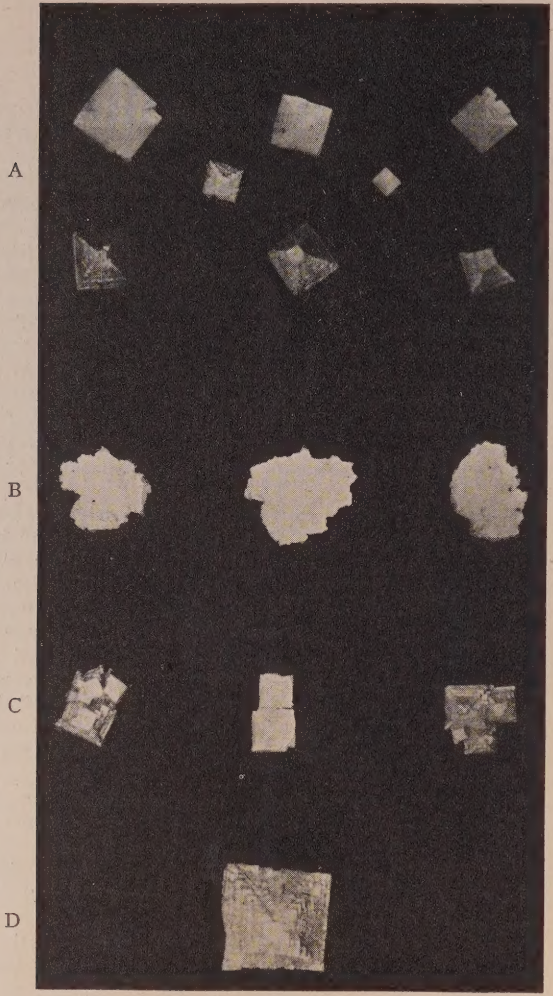


FIG. 16.—A. Hopper-shaped crystals formed by low temperature evaporation of brine without stirring. (Full size.)
B. Thin, flat mat formation of salt crystals formed by slow evaporation with moderate brine circulation. (Full size.)
C. Multiple-hopper crystals formed by low temperature evaporation with very slight brine circulation. (Full size.)
D. Thickened hopper-shaped crystal formed by slow evaporation on quiet brine surface.

and particles that have early lost their floating balance and gone to the bottom. When so filled the hopper eventually becomes a solid pyramid-shaped mass with a flat base (Fig. 17). The four tapered walls build up, and, under extremely slow evaporation as by solar heat, there finally develops a bunch of beautifully formed massive block-like crystals with sharp edges and corners, this being a typical formation of crude solar salt. (Fig. 18.)

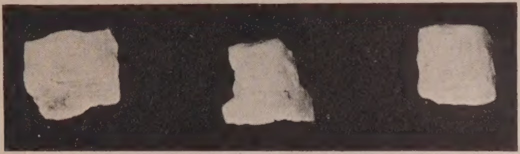


FIG. 17.—Hopper-shaped crystals grown to a solid form after sinking. (Full size.)

If the evaporation be repeated with brine near the boiling point, the

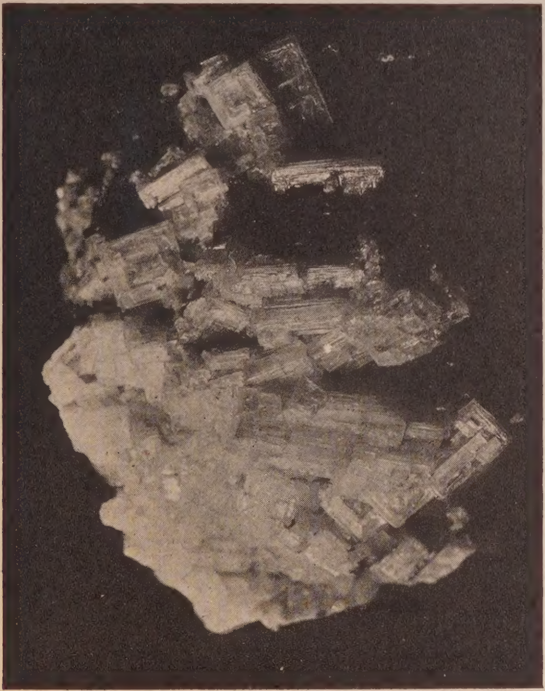


FIG. 18.—A large piece of solar salt just after removal from crystallization pond. Note characteristic crystalline structure.

escaping water vapor sets up local circulation in the liquid, agitating the surface and partly preventing hopper formation. Consequently the new-made salt particles sink while yet in the small hopper stage, either as partly completed hoppers, single cubes or as groups or bunches of united cubes. Violently boiling the brine, as in a vacuum evaporater, entirely prevents hopper formation and results in a product containing no flakes, only small cubes, as shown by Figs. 19 and 20.

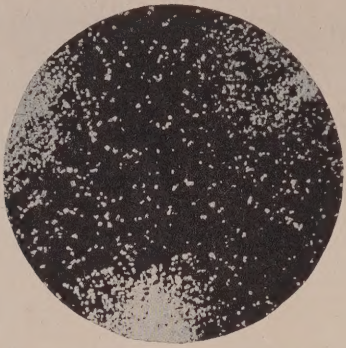


Fig. 19.—Vacuum pan salt. Note small cubical grains formed in violently boiling brine. (Magnification 3 diameters.)

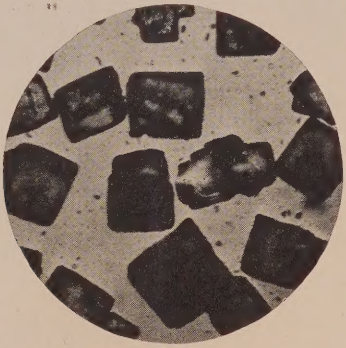


Fig. 20.—Vacuum pan salt of Fig. 19 enlarged 25 diameters.

From the foregoing we note:

a. Violent boiling or stirring always results in fine cubical particles of salt with no hoppers.

b. Near the boiling point evaporation with gentle stirring or local brine circulation produces a mixture of larger cubical particles and small, thin walled hopper crystals.

c. Slow evaporation without agitation produces hopper crystals with a large proportion of "flake" grains having thicker walls.

d. Very slow solar evaporation produces solidified and filled hoppers and block-like cubes, but almost no fine cubes or thin walled hoppers.

The shape, size, and physical characteristics of salt crystals are controlled in practice by manipulation of the brine during crystallization, and by the methods employed in draining, kiln drying and screening the crystallized product.

Proper manipulation to produce a required shape and size of grain is accomplished by controlling the brine temperature during crystallization, by the amount of mechanical stirring or agitation of the brine, and by the length of time the newly formed crystals are allowed to remain in the brine after sinking and before removal.

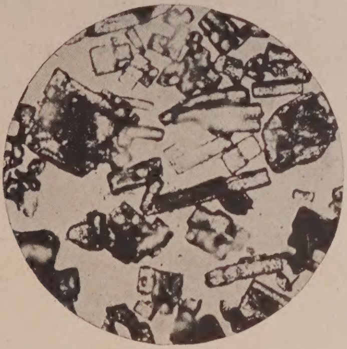


FIG. 21.—Small-grained, shaker salt prepared by the English "flash" grainer system, then kiln dried and screened. Note the thin hopper-shaped crystals. (Magnification 25 diameters.)

The grains in the marketed product are only approximately the shape of those produced in evaporation experiments, because the subsequent handling of the crystals in the refinery by centrifuging, storing in warehouse, steam drying in rotary kilns, screening to size, etc., breaks the crystals and effectually changes their original appearance.

Nevertheless, the nature of the final product—whether coarse grained or fine grained, whether flaky like filaments of mica, or cubical like minute dice—depends upon how the brine is evaporated.

Steam-heated vacuum pans operate by violent boiling and thus the salt produced consists of very small cubical crystals, flakes being absent. The particles are smooth and slightly rounded at the corners and edges (Fig. 20). When thoroughly dry and screened between certain size limits, vacuum pan salt pours and sifts readily.

The so-called English flash grainer system operates by first raising the temperature of the brine considerably above its boiling point in a closed heater, spurting the superheated brine into a drum or chamber where it "flashes," separating into (a) steam that escapes from the upper

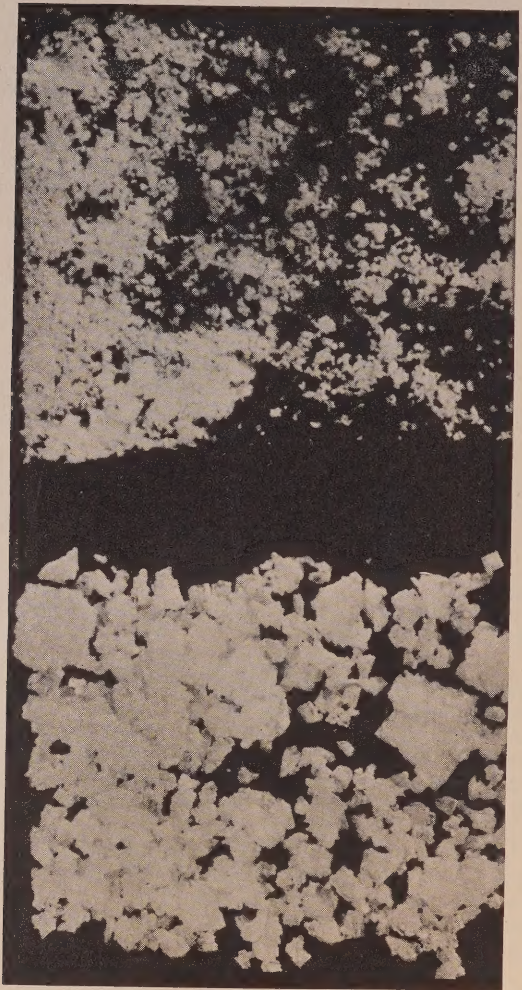


FIG. 22.—Composite grainer and vacuum pan salt. Upper—Manufactured in a highly heated grainer. Lower—Manufactured in a low heat grainer.

part of the drum, and (b) concentrated hot brine, filled with "seed" crystals, that escapes from the lower part of the drum into a mechanically raked grainer of large area. On the brine surface of the grainer the seed crystals rapidly form small, thin walled hoppers with only a minimum proportion of apex cubes. Flash grainer salt is light, fluffy and in mass has the appearance of "softness" on account of the volume of the hoppers composing it, and the extreme thinness of the hopper walls or flakes.

When dried and screened, the flash-grainer product viewed under a magnifying glass is seen to consist largely of thin splintered flakes which of course are the broken walls of the thin hoppers (Fig. 21).

The composite-salt grainer system operates by discharging dust salt from refinery screens, or fine grained salt from a vacuum pan, into a steam-heated mechanically raked grainer, in which concentrated brine is being evaporated at moderate heat. This super-charging results in bunching together the hopper crystals of the usual medium temperature grainer and the fine particles of added salt into more bulky crystalline units, making an imitation of relatively coarse standard grainer salt (Fig. 22). More rapid evaporation produces a finer grained aggregate (Fig. 22). Composite salt has a ready market and the method is useful to convert dust salt into a better marketable product without dissolving and re-evaporating.

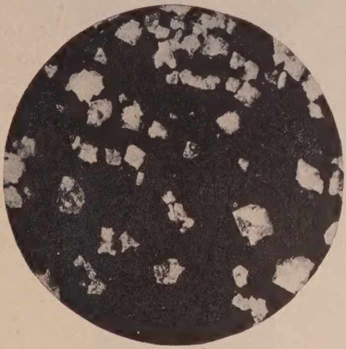


FIG. 23.—Standard grainer "common fine" salt. (Magnification 3 diameters.)

The steam grainer system is one of the most flexible and adaptable of all salt making systems, because it can operate with live steam to boil the brine and produce fine grained salt, or at lower temperatures to produce any of the flaky or hopper crystal formations (Fig. 23). It requires less skilled labor than the vacuum system, and can be operated at reduced capacity by shutting down one or more grainers when desired, whereas vacuum pans should operate only at full capacity. Mechanically raked grainers equipped with surface splashers or agitators permit hopper crystals to be sunk at any given stage of their growth and the product can be raked out either fast or slowly, giving close control of the physical characteristics of the finished product.

The direct fired pan system is similar to the steam grainer, but because of the furnaces beneath the steel pans and the danger of buckling the plates by overheating, when scale deposits on the hot surfaces, and the consequent high cost of upkeep, this system has been practically discarded throughout the United States. It usually heats brine unevenly, resulting in a badly mixed type of product.

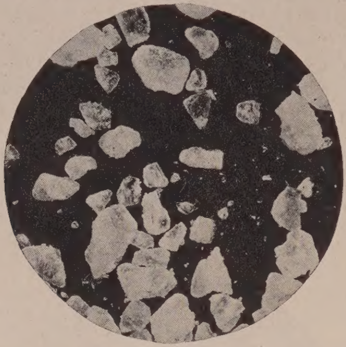


Fig. 24.—Crushed and screened solar salt. (Magnification 3 diameters.)

Solar salt evaporated from brine obtained from wells, and solar salt from sea water are mostly coarse and heavy crystals, but have a distinct characteristic shape approaching the original hopper form (Fig. 18). When cracked, crude solar salt breaks into somewhat cubical particles, but finer grinding breaks it into jagged and sharp-edged grains. The smooth cubical crystal form of vacuum pan salt and the flaky characteristics of steam evaporated grainer salt (Fig. 23) are not present in the finely screened grades of solar salt (Fig. 24).

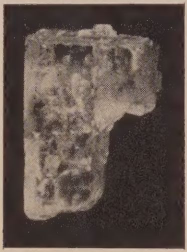


Fig. 25.—Crystal rock salt (mined), showing characteristic formation of crudes. (Magnification 3 diameters.)

Refining by Rewashing.

Only the very best solar salts can be converted into high grade refined salts without recrystallization. Careful control of the ponds during the evaporation season is required to produce a sufficiently high quality of salt for the purpose. Consequently only a few salines on the California coast make pure enough solar salt to be refined by washing.

The washing process is usually carried out in a revolving screen two-thirds submerged in an alkaline sodium chloride solution. After washing, the salt is screened to separate the coarse salt from the fine, the latter being sold as fish salt. The coarse salt, being the purer, is used for the preparation of the higher grades of salt, i.e. table and dairy. The wash-solution, which is obtained by dissolving high grade salt in fresh water, removes a part of the magnesium salts and other impurities from the crude salt. A fine precipitate of magnesium hydroxide forms in the wash liquor. The solution runs out through an overflow pipe, and then is returned to storage tanks where it is made alkaline again. The alkalies which are used in the wash solution include lime, sodium carbonate and bicarbonate. At times, crude trona from the alkali-lakes of California is used. In most cases, lime is sufficient; however, an excess of lime causes a fine white flocculent precipitate in the solution of the washed salt.

In some plants the washed salt is crushed and washed again in a centrifugal washer with a dilute solution of ultramarine. This produces a white salt.

The washed salt must be dried before grinding inasmuch as it contains from 1½ to 2½ per cent of water. Ordinarily, this is accomplished by heating in a revolving horizontal drier at a temperature of 190° to 210° F. At higher temperatures than 210° F., the salt becomes discolored (reddish-gray).

The drier usually is a rotary cylinder which revolves slowly as the salt passes through it. It is provided with steam pipes or a steam jacket or other heating equipment which raises the salt to 190°-210° F. Hot air is pumped through the drier to facilitate evaporation of the moisture contained in the salt.

Various types of machines are used for the grinding of the dried salt. Carr disintegrators and other grinders with beaters are quite satisfactory although they are seldom used. Roller mills are commonly used which are equipped with equal speed rollers. Impurities of light weight are removed from the salt by arranging an air-suction over the screens in the screening machine.

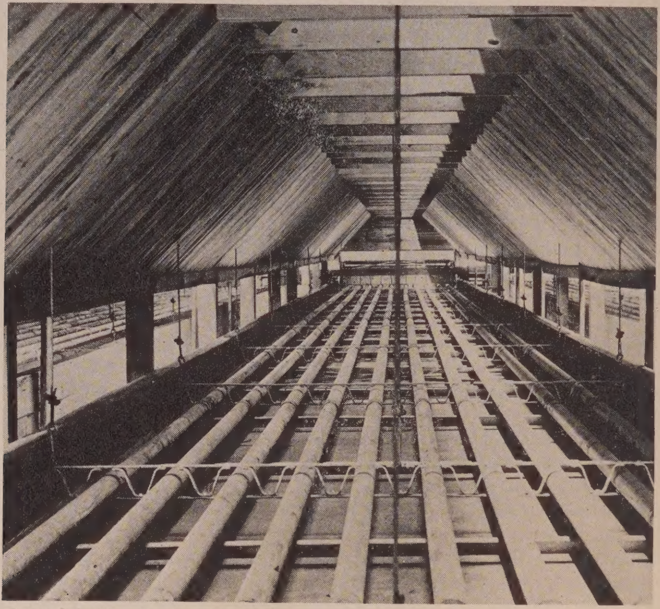
Shaker salt is made by mixing this salt with about 1 per cent of fine magnesium carbonate. Some of the salt manufacturers in the eastern part of the United States add fine sodium carbonate in place of the magnesium carbonate; but this cannot be used with sea salt unless it has been recrystallized, as it develops an unpleasant odor. In order to make the salt "free-running" 1½ per cent of white air-floated talcum powder is added instead of magnesium carbonate in some plants.

Refining by Recrystallization in Grainers.

In some American sea salt factories the refining is carried out by recrystallizing the salt in grainers. The crude solar salt is dissolved in a tank containing fresh water until a nearly saturated solution is prepared. This brine is limed, settled, preheated and then evaporated in the grainers.

A grainer consists essentially of a long, narrow, shallow vat built of wood or metal, supported on a framework, or of reinforced concrete supported on a foundation of sand. Live or exhaust steam is passed through pipes immersed in the brine in the grainer.

The crystallization of the salt begins on the surface and the little cubes which float on the surface gradually submerge into the hot brine. Simultaneously, in the course of the evaporation, new crystals form on the sides of the original cube, forming a cup-shaped concrement (Fig. 16), until it becomes so heavy that it sinks to the bottom. A scraping conveyor[1]



Courtesy Willcox Engineering Co.

FIG. 26.—Interior view of a salt grainer.

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[1] The illustration (Fig. 26) shows the construction of one type of mechanical raker which has been described by Willcox, "Salt Manufacture," *Trans. Am. Soc. Mech. Engr., 30* (1909), 1065-1085. This raker consists essentially of a framework comprising two steel angles placed near the bottom of the grainer. These two angles are connected by cross braces, and the resulting framework carries several feathering scraper blades extending across the grainer and supported at either end on the two side angles by horizontally projecting rocking pivots or fingers. The scrapers are placed about 8 feet apart, and the entire raker has a back-and-forth movement of about 9 feet, so that each blade travels about 1 foot ahead of the initial position of the next blade in front. The salt is thus gradually passed to the front of the grainer and up the incline. The side angles slide back and forth on flat cast iron shoes at suitable intervals along the bottom of the grainer. The piston rod of the hydraulic cylinder passes into the grainer through a stuffing box

carries the salt out of the grainer and deposits it on a platform where it is allowed to drain. After draining, it is dried usually in a revolving horizontal drier. Usually after the salt is in solution, a small amount of lime is added to it before it leaves the dissolving tank, and then it is allowed to stand long enough for the precipitated impurities to settle. This produces a clear white salt. Prior to the evaporation in the grainer, the brine is preheated and the gypsum precipitated.

Recrystallization in Vacuum Pans.

A number of factories on the Pacific Coast have adopted vacuum pans for recrystallization of the crude solar salt. The vacuum pans are both complicated and expensive, but, since the product is the finest that can be produced, this process is coming into use for the refining of sea salt. This process makes use of the lowering of the boiling point of a liquid resulting from decreasing the atmospheric pressure above the liquid. In practice it is impossible to attain nearly complete exhaustion of the chamber above the pan, but the partial vacuum maintained effects an appreciable lowering of the boiling point and consequently a distinct saving in fuel. In the multiple-effect vacuum-pan system, each vacuum pan acts not only as an evaporator, but also as a boiler producing heated vapor or steam for boiling in the next succeeding pan and as the condenser for the pan immediately preceding.

In the multiple-effect pans, the steam from the boiler plant, which has a temperature slightly above 212° F., enters the steam belt of the first vacuum pan and is condensed there. The heat from this steam is transmitted through the tubes and absorbed by the evaporating brine, which is under a vacuum of about 15 inches. As this brine boils, it gives off heated vapor which passes to the steam belt of the second vacuum pan. This vapor is at the temperature of the boiling point of the brine at a 15 inch vacuum which is approximately 175° F. If the liquor in the second effect is under a vacuum of 24 inches, the vapor at a temperature of 175° F. in the steam belt is amply hot to cause the liquor to boil. The vapor from the second effect is in turn led into the steam belt of the third pan and so on. Triple-effect vacuum pans are in common use for the recrystallization of salt, since a fourth effect is seldom profitable.

Inasmuch as the design and operation of the multiple effect vacuum evaporators is a highly specialized phase of salt manufacture, the details will not be discussed here. However, a brief discussion of the size and design of a simple vacuum pan will not be out of place. The diagram (Fig. 27) by Downing [2] gives the general construction of a simple vacuum pan and Table 3 gives the relative proportions of the pan. The body or shell of the larger vacuum pans which are of greater diameter than ten to twelve feet usually are made of cast iron; in smaller pans steel is used. The tubes are made of either steel or copper. Steel, copper or tobin-bronze are used for the construction of the tube sheets. The customary

in which are several rings of metallic packing. The cylinder is usually about 8 inches in diameter with a 9-foot stroke. It makes a stroke in about two minutes, bringing up a load of salt every four or five minutes.

[2] *Chem. Age, 30* (1922), 17.

dimensions for the tubes in the smaller pans are 2½ inches (o. d.) by 48 inches. In the larger pans the 2½ inches tubes are also used but the tubes are longer and are sometimes as long as 72 inches.

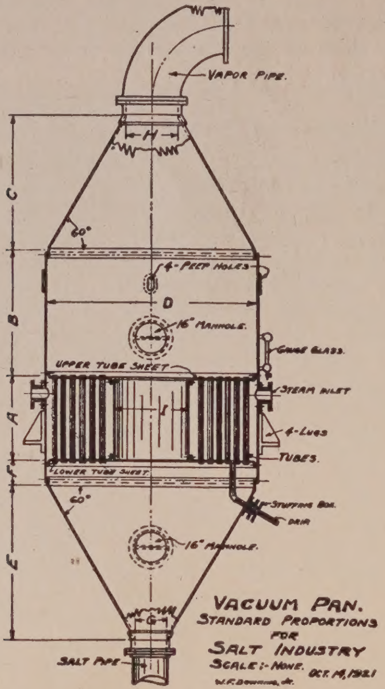

FIG. 27.—Diagram of a vacuum pan especially designed for the manufacture of salt.

Downing gives the following data for the capacity and efficiency of vacuum pans:

> The capacity of a single effect salt pan is, roughly, one barrel of salt of 280 pounds in twenty-four hours for each 2½ x 48-inch tube, or one barrel of salt of 280 pounds for each 2½ square feet of heating surface in twenty-four hours. In other words, the capacity of a single effect pan in barrels per twenty-four hours is, roughly, equal to the number of four-foot tubes that it contains. This figure can be exceeded considerably if the pan is clean and artificial circulation is resorted to.
>
> The efficiency of salt pans is generally 70 to 80 per cent. The salt made is usually, for single effects, 12 to 14 barrels of salt per ton of coal; for double effects, 21 to 24 barrels of salt per ton of coal; for triple effects, 33 to 36 barrels of salt per ton of coal and for quadruple effects, 42 to 46 barrels of salt per ton of coal. The above figures depend upon the grade of coal used.

The chief difficulty encountered in the crystallization of salt in vacuum pans is the formation of a hard porcelain-like scale of gypsum on the inside of the vacuum pan. This scale is a very poor conductor of heat

TABLE 3

SOME STANDARD PROPORTIONS OF A VACUUM SALT PAN

Symbol	Description	Dimension	Dimension is in:
A	Out to out of tube sheets	3′ 10½″	Ft. and in.
B	Working space	6′ 0″	Ft. and in.
C	Top cone height	.6 x D	Ft.
D	Diameter of pan	Datum	Ft.
E	Bottom cone height	.75 x D	Ft.
F	Neck below tube sheet	12″	In.
G	Salt leg diameter	.15 x D, Min.' 1⅓	Ft.
H	Vapor pipe diameter	.3 x D	Ft.
I	Downtake diameter	.6 x D	Ft.
J	Steam inlets diameter (2 openings)	.12 x D	Ft.
K	Length of tubes	4′ 0″	Ft. and in.
L	Number of tubes	7.75 x D^2	No
M	Outside diameter of tubes	2½″	In.
N	Gauge of tubes	14	No
O	Ct'r to ct'r of tubes	3½″	In.
P	Heating surface	20 x D^2	Sq. ft.
Q	Capacity of pan in 24 hrs.	7.75 x D^2	Bb'ls
R	Velocity of brine through tubes	30	Ft. per sec.
S	Velocity of brine through downtake	3	Ft. per sec.
T	Velocity of vapor	300	Ft. per sec.
U	Velocity of steam at inlets	100	Ft. per sec.
V	Steam pressure	5	Lbs.
W	Vacuum	27	In.

and reduces the efficiency of the apparatus to a large extent. The removal of this scale, once it has formed, is a difficult operation. It is accomplished either by overheating the underlying metal to loosen the scale or by simply scraping it off.

The formation of the scale may be avoided in several ways. A small amount of calcium chloride may be added to the brine before it is run into the vacuum pans and then it may be heated in a grainer-like tank to a temperature of about 150° F. Or a small amount of trisodium phosphate may be sucked into the vacuum pans during the evaporation. The latter operation causes the precipitation of flocculent calcium phosphate instead of the troublesome gypsum.

A low brine level in the pans and violent agitation of the brine during crystallization produces small, fine grains of salt; whereas a higher brine level causes coarser grains.

The crystallized salt drops down to the bottom of the vacuum pan and may be drawn off intermittently from the bottom or may be caught either in a "salt-catcher" or in a "leg" or "elevator boot."

As the boiling brine is under a partial vacuum, the level of the brine in the elevator housing above the boot is lower than that in the pan. The salt passes through the brine in the elevator housing in a bucket conveyor. Sometimes the salt is washed in the elevator with a pure salt solution. After washing it is conveyed to a centrifuge where it is partially dried and finally to a revolving cylindrical steam-heated drier, which has been previously described.

American Grades of Refined Sea Salt.

The following grades of refined salt are considered commercial California salts:

No. 1 Mill Salt.—This salt is "three-fourths ground" size and has been treated and dried.

No. 2 Mill Salt.—This salt is the same as No. 1 except that it is somewhat coarser.

Coarse Granulated.—Treated, dried salt which has been ground to suitable size for cooking and preserving.

Fine Granulated.—Treated, dried salt which has been ground to a size suitable for table use.

Bakers' Fine.—This grade is finer than table salt and is used in dairies and also in some chemical industries.

Shaker Salt.—Especially prepared table salt containing finely powdered magnesium carbonate or some other substance to produce "free-running" salt.

The uses for the various qualities of commercial salts are indicated below:

Hide Curing.—Coarse, solar salt.

Meat Packing.—Medium coarse, flaky steam grainer salt.

Sheep Salt.—Medium fine, crushed solar, crushed rock or coarse grainer.

Stock Salt.—Coarse cracked solar, rock, hydraulic pressed fifty pound blocks, coarse grainer.

Cheese Salt.—Grainer flake—medium.

Butter Salt.—Steam grainer, light flake, medium fine. For butter and cheese, a thin flake permeates better than vacuum or crushed solar, without forming local pockets of brine that give a stinging taste and make the butter seem too salty. More pounds of flake can be used for a given quantity of butter, and dairymen realize that salt is cheaper than butter.

Kitchen Salt.—Commonly called "table salt," flake grainer, kiln dried, screened. Ground and dried solar or rock salt screenings.

Shaker Salt.—For dining table use—vacuum pan, grainer flake fines, kiln dried, small screened and usually powdered with carbonate of magnesia to keep it free-running.

Fishery Salt.—For dry-salting cod, haddock, cusk, pollack, etc., in butts. Pure coarse flaky steam grainer salt which is free from calcium and magnesium should be used. The flakes take up the fish juices rapidly, giving a faster rate of "strike" or penetration. Magnesium and calcium in fish salt causes "case-hardening," that is, curing the outer parts of the fish but giving lesser preservative action inside.

The Recovery of By-Products from Bittern.

The Importance of By-Products.

Although salt has been produced by the solar evaporation of sea water for many centuries, no important use had been made of the bittern or mother liquor from the salt crystallizations until comparatively recent times when Balard worked out the well known process for the recovery of sodium sulphate and potassium chloride from the bittern. This process, with modifications by Merle and Péchiney, is in use to-day at Giraud-en-Camargue at the mouth of the Rhone River. Although Balard's process was entirely successful at the salt works at Giraud, few attempts have been made to utilize salt bitterns elsewhere until recent years. Magnesium chloride, magnesium oxychloride cements, and bath salts have been recovered from the bitterns obtained in the California salt works for a number of years, and, during the World War, potassium chloride was recovered at some salt works. Recently there has been an attempt to recover by-products from the salt works at the Pond of Cagliari in southern Sardinia.

The discard of the mother liquors from the salt works represents a tremendous waste, for the mother liquor from 100,000 tons of salt contains 2,800 tons of potassium chloride, 27,300 tons of magnesium chloride ($MgCl_2 \cdot 6H_2O$), 16,000 tons of magnesium sulphate ($MgSO_4 \cdot 7H_2O$) and 240 tons of bromine. At the present price of bromine ($0.20 per pound) this substance alone would be worth $96,000.

Detailed analyses of various bitterns from some California salt works are given in Table 4.

Balard's Process.

About the year 1850, Balard[3] perfected the process, which now bears his name, of recovering common salt, sodium sulphate, and potassium chloride from the solar salt bitterns. His process, in general terms, consisted in the alternate concentration and cooling of the mother liquor of the sea salt works, so as to secure by successive crystallizations the three products mentioned above and also a concentrated magnesium chloride solution. This process is described briefly below:

Bittern of about 1.28 sp. gr. was evaporated to a density of 1.32 and under such conditions deposited magnesium sulphate containing a nearly equivalent amount of sodium chloride. This *sels mixtes* was converted into sodium sulphate and magnesium chloride by dissolving it in water and allowing it to crystallize during cold weather under which conditions nearly pure sodium sulphate crystallized out.

The mother liquor from the *sels mixtes* was held until cold weather when it was run into shallow concrete tanks; nearly pure magnesium sulphate was deposited. This magnesium sulphate was converted into sodium sulphate by adding to it 1.5 of its equivalent of sodium chloride, dissolving, and allowing it to crystallize at a temperature below 0° C. Nearly pure sodium sulphate crystallized out under these conditions.

The mother liquor from the magnesium sulphate crystals was stored through the winter and evaporated further during the succeeding spring and summer. This evaporation caused the crystallization of the potassium chloride together with a portion of the magnesium chloride as an impure carnallite $KCl.MgCl_2.6H_2O$ leaving in solution little else but magnesium chloride, which was discarded. A considerable proportion of the potassium

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[3] London, Great Exhibition of the Works of Industry of all Nations of 1851, *Jury Rept. 1*, 93-4.

TABLE[a] 4

ANALYSES OF BITTERNS FROM SEA WATER[b]

Serial No.

	11B 198	11B 199	11B 200	11B 201	11B 202	11B 204	11B 205
K	8.2	13.4	13.2	14.6	21.5	35.0	11.8
Na	72.6	62.7	60.9	24.5	4.7	93.5	55.1
Ca	1.2	2.2	0.6	0.5	1.0	0.2	1.1
Mg	24.0	23.4	50.6	62.7	79.4	8.6	43.9
Cl	179.2	176.6	179.4	183.3	220.1	180.4	190.8
SO_4	30.0	31.4	53.6	74.2	62.0	29.0	55.8
Br	3.0	2.0	2.0	3.0	2.0	2.0	2.8

CONVENTIONAL COMBINATIONS

	11B 198	11B 199	11B 200	11B 201	11B 202	11B 204	11B 205
KCl	15.6	25.5	25.5	27.8	41.0	66.7	22.5
NaCl	184.2	159.1	154.6	62.1	11.9	237.6	129.7
$CaCl_2$	..	..	..	..	..	..	..
$MgCl_2$	77.1	84.5	110.8	176.3	256.9	5.8	132.9
Na_2SO_4	..	..	..	..	..	..	..
$CaSO_4$	4.0	7.4	2.3	1.7	3.3	0.6	3.7
$MgSO_4$	33.9	39.8	65.0	91.5	75.3	35.8	65.4
$MgBr_2$	3.4	3.4	3.4	3.4	2.3	2.3	3.2

[a] From "Composition of the Salines of the United States," by J. W. Turrentine. *J. Ind. Eng. Chem.*, *5* (1913), 19-24.

[b] R. F. Gardner, analyst.

DESCRIPTION OF SAMPLES

11B 198. Leslie Salt Refining Works, San Mateo, Calif. Mother liquor; representative sample from near northwest corner of mother-liquor pond.

11B 199. Leslie Salt Refining Works, San Mateo, Calif. Sample from southeast corner of mother-liquor pond.

11B 200. Leslie Salt Works, San Mateo, Calif. Mother liquor from salt-making pond (solar evaporator or "salt garden"); pond has been "making salt" during the summer.

11B 201. Oliver Salt Works, Mt. Eden, Calif. Mother liquor from slop pond. Represents an accumulation of 5 years.

11B 202. Oliver Salt Works, Mt. Eden, Calif. Mother liquor which has been subjected to some special treatment.

11B 204. California Salt Co., Alvarado, Calif. Mother liquor from the slop pond. Represents about 3 years' accumulation, with the abstraction of considerable quantities for "forcing" purposes and the addition of small quantities of other waste liquors.

11B 205. Pioneer Salt Co., San Francisco, Calif. Mother liquor, one years' accumulation.

chloride was removed from the carnallite by washing, first with a potassium chloride solution, and then with water.

Merle and Péchiney improved Balard's process by making use of artificial refrigeration for the cooling of the liquors; moreover, they introduced other new features in order to prepare anhydrous sodium sulphate.

Merle and Péchiney's Modification.

Wurtz[4] and Lunge[5] have described Balard's process of utilization of the bitterns obtained in the manufacture of solar salt as elaborated by Merle and Péchiney. The mother liquors from the crystallizing ponds are concentrated from a density of 1.2889 (32.5° Be.) to 1.3182 (35.0° Be.) in shallow reservoirs. During this evaporation low grade salt crystallizes out. Further evaporation causes the deposition of *sels mixtes,* a mixture of equivalent parts of sodium chloride and magnesium sulphate (about 45 per cent sodium chloride and 55 per cent magnesium sulphate). The double salt is redissolved in water to form a solution of 1.2609 (30° Be.) density; the resulting solution is cooled by means of artificial refrigeration to —6° C. As the solution cools, crystals of Glauber's salt ($Na_2SO_4.10H_2O$) form. The following reaction takes place:

$$2NaCl + MgSO_4 = Na_2SO_4 + MgCl_2.$$

The cold solution is then filtered. The mother liquor consists of a solution of impure magnesium chloride and is either used for the manufacture of magnesium oxychloride cement or is discarded. The crystals of Glauber's salt are freed from water and transformed into anhydrous sodium sulphate by a unique process. The Glauber's salt is mixed with 45 per cent of *sels mixtes* and heated to 80° C. Above 33° C. the Glauber's salt decomposes, giving up its water of crystallization to the *sels mixtes.* The sodium sulphate is separated from the hot solution in a centrifuge. The filtrate consists of *sels mixtes* and is added to the main solution of this substance. The sodium sulphate produced in this manner is almost entirely free from magnesium salts but contains about 4 per cent of water.

The filtrate from the *sels mixtes* is either cooled by artificial refrigeration to a low temperature or is run into reservoirs and allowed to remain until winter when it cools down to below 12° C. At this temperature, magnesium sulphate crystals begin to separate. These are separated from the main body of the cold solution, and, after washing, are dried and sold. The separation of the magnesium sulphate causes the density of the solution to decrease to about 1.3004 sp. gr. (33.5° Be.).

The mother liquor from the magnesium sulphate crystals is evaporated in shallow pans until crystals begin to form in the solution which usually occurs when the liquor reaches a density of 1.3063 (34° Be. at 0° C.). The mother liquor from the carnallite crystals, which consists chiefly of magnesium chloride, is evaporated simultaneously until it reaches a density of 1.3809 (40° Be.). The two solutions are mixed, while hot, which causes the deposition of more *sels mixtes.* This is separated from the hot mother liquor, and added to the main bulk of *sels mixtes.* When the mother liquor is cooled, all the potassium that it contains separates as carnallite ($KCl. Mg Cl_2.6H_2O$). Part of the mother liquor is evaporated further until it reaches a density of 1.3809 (40° Be.), when it is used for the crystallization of more carnallite; the remainder is utilized later in the preparation of bromine.

The crude carnallite contains about 20 per cent of potassium chloride, and is in a very finely divided condition; therefore it is relatively easily decomposed. It is washed with the wash liquor from the last treatment of carnallite (see below). This partially decomposes the carnallite, leaving a residue which consists of a mixture of carnallite and potassium chloride containing about 40 per cent potassium chloride. The wash liquor produced in this operation contains chiefly magnesium chloride with a small amount of potassium chloride. This liquor is added to the liquors used in the crystallization of the carnallite. The mixture of carnallite and potassium chloride is treated with a small amount of fresh water which dissolves most of the magnesium chloride from the double salt, carnallite, leaving a potassium chloride of 65-82 per cent purity. This product is usually sold as a fertilizer. The wash water obtained in the second washing is used for the first washing of the crude carnallite.

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[4] Hoffman's *Ber. Wiener. Austellung, 1* (1875), 410.

[5] *Chem. Ind., 6* (1883), 225-231.

Table 5 is an outline of the process in use at Giraud in southern France.

The California Process.

Little use was made of the bitterns obtained in the manufacture of solar salt in northern California until the event of the World War, when the high prices of chemicals and the general economic situation brought about the utilization of waste products in many industries of this country. Among the by-products, which have been prepared from the sea salt bitterns, are magnesium sulphate, magnesium chloride, potassium chloride, bath salts, low grade salt, magnesium oxychloride cements and artificial stone. Metallic magnesium and bromine have been prepared on a small scale during experimental work on the utilization of bittern but their production commercially was not successful for economic reasons.

Since the close of the war, a readjustment has taken place and some of the war-time processes have been discontinued because of the lower prices of chemicals. During 1921, the only by-products which were being manufactured were bath salts, magnesium chloride, magnesium oxychloride cements and artificial stone.

In working up the end-liquors from solar salt manufacture, the bittern is conducted from the crystallizing ponds to concentration ponds where the evaporation is continued until the bittern reaches a density of 1.2719 to 1.2832 (31 to 32° Be.). During this evaporation some impure salt (sodium chloride) crystallizes out. The impurities in this salt consist chiefly of the sulphates of magnesium and sodium. The cooler the weather during evaporation, the more of these sulphates crystallize out. Magnesium sulphate is precipitated in quantity at a higher temperature than sodium sulphate.

Two processes are used in the separation of the salts contained in the bittern. One of these processes involves the refrigeration of the brine and is called the "freezing out" process. In the other process, the sodium chloride is removed first by a preliminary evaporation, then the magnesium sulphate is removed by fractional crystallization. Next the double salt of magnesium and potassium chlorides is crystallized, and, finally, the remaining magnesium chloride is recovered. The last-mentioned process involves more accurate chemical control, but the products are much more valuable.

TABLE 5

Showing Products of Balard's Process for Utilization of Solar Sea Salt Bittern as Used at Giraud, France

Mother Liquor
approximately 1.2289 sp. gr. (32.5° Be.) evaporated gives:

- (1a) Low grade salt
- (1b) Mother liquor evaporated to 1.3182 sp. gr. (35° Be.), gives:
  - (2a) *Sels mixtes,* which is mixed with that from 4b and 6a and dissolved to form a solution of 1.2609 sp. gr. (30° Be). This solutions is then cooled to —6° C., and gives:
    - (3a) Crystalline Glauber's salt, which is melted at 80° C. with 45 per cent of *sels mixtes* and is centrifuged while hot.
      - (4a) Anhydrous sodium sulphate
      - (4b) Solution of sels mixtes, returned to (2a).
    - (3b) Mother liquor consists of impure magnesium chloride which is either used for the manufacture of magnesium oxychloride cement or is discarded.
  - (2b) Mother liquor, is cooled by storage until winter to 12° C., gives:
    - (5a) Epsom salts, a part of which is sold, a part used in the correction of (2a).
    - (5b) Mother liquor of 1.3004 sp. gr. (33.5° Be.) is preheated in heat interchanger by hot liquor (6b). Then evaporated to 1.3063 sp. gr. (34° Be.) and mixed with 1.3809 sp. gr. magnesium chloride solution from (7b) and while hot gives:
      - (6a) Sels mixtes, returned to (2a).
      - (6b) Mother liquor, when cooled gives:
        - (7a) Crude carnallite containing 20 per cent KCl, treated with liquor 10b gives:
          - (8a) Intermediate product containing 40 per cent KCl, washed with fresh water gives:
            - (9a) Potassium chloride of 65-82 per cent purity.
            - (9b) Liquor which is used in the washing of (7a).
          - (8b) Liquor containing much $MgCl_2$ and a little KCl and is added to solution (5b).
        - (7b) Mother liquor, part of which is evaporated to 1.3809 sp. gr. and returned to (5b); the remainder is used for the preparation of bromine.

Separation of the Salts by Freezing Out the Sulphates.

The concentrated bittern is evaporated in an open pan or vacuum pan until sodium chloride ceases to separate. If the evaporation is effected in a vacuum pan, the temperature must not be too low or salts other than sodium chloride will be precipitated in large quantities. The difference between the solubility of common salt in hot and cold water is comparatively slight, whereas the other bittern salts are all very soluble in cold water. Thus it is very easy to separate the sodium chloride from the remaining salts by the evaporation of the bittern at high temperatures. The chief impurity in the sodium chloride is gypsum, which is only slightly soluble in water at any temperature.

The evaporation is continued until the density of the brine reaches 1.3063 (34° Be.) or slightly higher. Then the mother liquor is cooled down in a refrigerating machine. The following salts separate: sodium chloride, sodium sulphate ($Na_2SO_4 . 10H_2O$), and artificial carnallite ($KCl . MgCl_2 . 6H_2O$). Under certain circumstances, small amounts of magnesium sulphate and potassium sulphate separate at this stage. These salts are often mixed with the impure salt from the bittern pond and the salt deposited upon preliminary evaporation in the vacuum pan and sold as bath salt for medical purposes (the so-called Kreuznach medical bath salt). Sometimes these salts are mixed with an equal quantity of magnesium chloride before they are sold as bath salt; this improves their quality and makes them especially desirable for medical purposes because of their stimulating effect on the skin.

The mother liquor remaining after refrigeration contains little else but magnesium chloride and bromide. It is evaporated to a point where the liquor will solidify to a mass of crystals upon cooling; this will happen when the density of the solution reaches 1.3675 (39° Be.). The liquor is then run into cooling tanks. If it is dark-colored, a little chlorine is often added to bleach it. Upon cooling slightly, a little sodium chloride settles to the bottom before solidification.

If the magnesium chloride solution contains sulphates, a little barium chloride is added to it. This prevents the formation of white efflorescence, if the magnesium chloride is used for the manufacture of magnesium oxychloride cements.

After centrifuging the magnesium chloride crystals, they are packed in drums containing 150 to 200 pounds.

Fractional Crystallization to Recover Magnesium Sulphate, Potassium Chloride and Magnesium Chloride.

The concentrated bittern is evaporated in vacuum pans, as in the preceding method, until it reaches 34° Be. By this time, most of the sodium chloride has crystallized, and is removed from the pan. The evaporation is then continued. From time to time, samples of the liquor are removed and cooled in test-tubes; when, upon cooling, sufficient magnesium sulphate crystallizes and settles to the bottom to fill the tube one-quarter full, the main body of the solution is cooled. The salts which crystallize contain 60 to 75 per cent of magnesium sulphate. These salts are removed, and recrystallized to obtain pure Epsom salts, or are used in the manufacture of magnesia.

The evaporation of the main body of the liquor is then continued, until upon cooling a test sample, a considerable amount of the double salt of magnesium and potassium chloride crystallizes out. These crystals have a "sandy" appearance, and appear when the liquor reaches a density of 1.3182 to 1.3303 (35-36° Be.). When this point is reached the liquor is cooled and the artificial carnallite is removed by centrifuging. The mother liquor now contains little else but magnesium chloride and bromide. The evaporation of this liquor is continued and the magnesium chloride is recovered as in the method previously described.

The carnallite is dissolved in hot water and the potassium chloride is separated from the magnesium chloride. Analytical control of the decomposition of the carnallite is necessary. The separation of the carnallite into potassium chloride and magnesium chloride must be repeated one or more times, for the first crystallization does not produce pure potassium chloride.

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Chapter 4.

Iodine and Potash from Seaweeds—European and Japanese Processes.

Characteristics of Algæ.

"Seaweeds" is the common name for marine algæ. Algæ are relatively simple plants which ordinarily grow either under or partly under water. They lack true differentiation into root, stem and leaf, and are reproduced by spores. A spore usually consists of a single cell and differs from a seed in that it does not contain a ready-formed embryo plant. Algæ are chlorophyllous plants, and therefore are able to synthesize carbohydrates, such as sugars and pectins, from carbon dioxide and water by means of the energy which they receive from the sun's light rays. Chlorophyl gives the characteristic green color to the green algæ (*Chlorophyceæ*). In the blue-green algæ (*Cyanophyceæ*), this green coloring matter is mixed with a blue pigment. In some algæ the green color is almost completely masked by a red pigment; these algæ are therefore known as the red algæ (*Rhodophyceæ* or *Florideæ*). A brown pigment called phycophæin is found in the brown algæ (*Phaeophyceæ*) in addition to the chlorophyl. The real basis for the division of the algæ into these four subclasses is certain differences in their method of reproduction, but the colors correspond so closely with these differences in reproduction that it is usually possible to assign an algæ to its proper subclass by its color.

The word kelp is used in several different senses. In Europe kelp usually means the ashes of seaweeds which are used for the manufacture of potassium salts and iodine, although some persons use the term to designate all seaweeds from which these ashes are obtained. Along the Pacific Coast of the United States the large brown seaweeds are called kelp. The seaweeds, thus designated, include *Macrocystis pyrifera, Nereocystis luetkeana, Alaria fistulosa* and a few others. In this chapter the word kelp will be used to mean seaweed ash, as it is by the English seaweed burners.

Varieties of Algæ Utilized.

Small amounts of many seaweeds are used in Europe for the manufacture of iodine. The most important species include *Laminaria digitata, Laminaria bulbosa, Laminaria saccharina, Laminaria stenophylla, Fucus serratus, Fucus nodosus, Fucus vesiculosus, Himanthalia lorea, Chorda filum, Fucus stenolobus, Fucus alaria,* and *Fucus siliquosus.*

The botanical characteristics of these algæ are given below:

Laminaria digitata or *Fucus digitata* (common names: Sea-girdles, Tangle, Sea-staff, Sea-wand):—a perennial, olivaceous brown alga. Its stem is woody and varies from two to six feet in length and from half an inch to two inches in diameter. The solid cylindrical stem expands into a leathery, roundish-oblong frond from two to eight feet in length and from one to two feet in width, deeply cleft into several segments.

Laminaria stenophylla. Very similar to the above and classed by some as a variety of *Laminaria digitata.* It is distinguished by its longer stem and more slender frond.

Laminaria bulbosa or *Fucus bulbosa* (Bulbous-rooted tangle, Sea-furbelows, Furbelowed-hangers):—a perennial found on rocky shores. When young the stem is flat with a waved margin, but as the plant grows older it expands into a large, bulbous, hollow body about six inches in diameter. The fronds are oblong, deeply cleft into many linear segments.

Laminaria saccharina (Sweet tangle, Sea-belt):—a common perennial, olive brown alga, found on rocks between tide-marks. The cylindrical stem is from an inch to a foot in length. The frond is 2 to 12 feet long and 4 to 16 inches wide, with waved margins and is bullated and rugose and thickened at the center. It is called saccharina, as it is very sweet because of its high mannite content.

Fucus serratus (Serrated seaweed. Black wrack, Prickly tang):—a common perennial, dark olive green alga, found on rocky sea shores. Its fronds are serrated, midribbed, without air-vessels and about 6 feet long and about 2 to 2½ inches wide.

Fucus nodosus (Yellow-wrack, Knobbed-wrack, Sea whistles):—a common, glossy, olive green perennial alga found on sea shores. Its holdfast is a large, hard, conical mass from which spring several fronds 2 to 6 feet long which are once or twice forked and irregularly pinnated with alternate simple branches. It is extremely tough and leathery.

Fucus vesiculosus (Sea-ware, Bladder fucus, Kelp-ware, Black-tang, Lady wrack, Swine-tag):—very abundant on all sea shores. Its holdfast is a hard, flat disk. The fronds, 1 to 3 feet in length, are thick, linear, midribbed, and the air-vessels globose, mostly in pairs.

Fucus siliquosus (*Halidrys siliquosa*):—a common, olive brown perennial alga found on rocks in the sea at half-tide level. Fronds are 2 feet or more in length, ½ inch in diameter becoming narrower, compressed and two-edged upwards, and from one to two lines in breadth, bi-tripinnate. The branches alternate, erecto-patent, two-edged, often changed into vesicles. Its structure is more or less woody in the older parts. It is readily distinguished from every other alga by the curious structure of its air-vessels which are divided transversely by extremely thin membranous diaphragms, and these are curiously supported by very slender filaments stretched from diaphragm to diaphragm.

Himanthalia lorea (Fucus loreus):—a common biennial, dark olive green alga, found on rocky sea shores. Fronds are gregarious, top-shaped, about an inch high; receptacles 2 to 10 feet long, coriaceous and thong-like.

Chorda filum (Sea-laces, Cat-gut, Dead men's ropes, Lucky Minny's lines):—a common annual olive brown alga found on rocks and stones in the sea between tide-marks. Its fronds are cartilaginous, clothed with pellucid hairs, and are from a quarter to half an inch in diameter and from one to forty feet long, tapering to each extremity.

History of the Utilization of the Ash of Seaweed.

Seaweeds were burned on the European coasts to make kelp ashes long before iodine was discovered. These ashes were used as a source of alkali needed for the manufacture of soap, glass and alum. During the eighteenth century the chief sources of potash and soda were wood ashes, seaweed ashes and the ash of wine lees. At the beginning of the nineteenth century, Scotland alone produced about 20,000 tons of kelp ashes annually which were valued at 400,000 pounds sterling.

The methods used in the preparation of "pot-ash" in the eighteenth century were simple. Mitchell[1] described them briefly as follows:

> They have a very different way in the north of England of reducing their kelp to pot-ash, which they use for making alum. This is made from the different kinds of Fuci, or sea weeds thrown up on the shore, or gathered on the rocks; which they dry a little in the sun and afterward burn them in a kiln, built of stones they find upon the shore, in a cylindrical form, and about two feet or less in diameter. In this they first burn a small parcel of the herb, and before it is reduced to ashes they throw on more till the kiln is full, or their materials are expended. This is said to reduce the ashes to a hard and solid cake, by the heat of the kiln and the quantity of salt in the herb, which makes what is commonly called kelp-ashes.

These kelp-ashes were refined for use in making soap, glass, etc., by dissolving the soluble salts from the crude product and evaporating the resulting solution to dryness. If the caustic alkalies were desired, they were prepared by treating the solution with lime. This produced a mixture of potassium and sodium hydroxides and calcium carbonate. The insoluble carbonate was separated by filtration.

When the manufacture of soda from common salt commenced, the value of the seaweed ashes dropped rapidly, and although the discovery of iodine in 1812 increased the value of the ashes, the European industry has never reached its former height again. Iodine was not produced from seaweed in large quantities until the year 1841. The price of iodine increased until 1873. About that time the recovery of iodine from the mother liquors obtained in the manufacture of sodium nitrate from caliche commenced. At the present time the bulk of the iodine of commerce is obtained from crude Chile saltpeter.

Geographical Distribution of European Industry.

Naturally the European seaweed iodine industry is located along the seacoast in the proximity of the beds of algæ which contain sufficient iodine to be of commercial value. The present-day industry is located in three important centers, viz.: Scotland, Normandy and Norway. A small amount of seaweed is also burned in Sweden, Denmark, Spain and Germany. Chile now produces nearly three times as much iodine as the entire European iodine-seaweed industry produces. About 400,000 long tons of green seaweed are collected annually in Great Britain, France and Norway; of this about 100,000 tons are gathered in France. The 400,000 tons of algæ yield about 175 long tons of iodine, 10,000 tons of potassium salts, 3,000 tons of crude salt and 7,000 tons of crude washing soda. In 1911, Europe produced 385,000 pounds of iodine, whereas the Chilean nitrate industry produced about 1,100,000 pounds of iodine. In that year, Japan produced about 117,493 pounds of iodine and 136,300 pounds of potassium iodide. In recent years the Japanese iodine industry has grown very rapidly; although the World War stimulated the European potash and iodine industry there has been no growth corresponding to that of the Japanese industry.

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[1] *Trans. Roy. Soc. London, 45* (1748), 541-563.

The British Seaweed-Burning Industry.

Importance of the Industry.

The production of kelp from seaweed in Great Britain was commenced about the year 1720 and gradually expanded until early in the nineteenth century when the soda industry eliminated the need for soda from this source. The demand for iodine revived the industry about the year 1840 but in 1872 when new sources of iodine were discovered the English kelp-burning industry declined again. The event of the World War brought about a temporary rejuvenation of kelp-burning as a source of potash; but it is probable that the industry will never again reach its former importance.

Varieties Utilized.

The five most important varieties utilized for the production of kelp and their iodine content, as given by Stanford,[2] are listed below:

			Per cent of dry kelp
Laminaria digitata	(A)[3]	Stem	0.4535
	(B)	Frond	0.2946
Laminaria saccharina	(C)		0.2794
Fucus serratus	(D)		0.0856
Fucus nodosus	(E)		0.0572
Fucus vesiculosus	(F)		0.0297

Hendrick[4] has made a more detailed examination of the composition of the important British seaweeds; his analyses are presented in Tables 6 and 7. These analyses indicate that *Laminaria digitata* and *Laminaria stenophylla* are much richer in potash and iodine than the seaweeds of the *Fucus* family that are burned for kelp.

There has been some disagreement among investigators as to the form of iodine in marine algæ. Eschle,[5] and Okuda and Eto[6] found that practically all of the iodine contained in seaweed is in organic combination, whereas Tsukamoto and Furakawa[7] concluded that the iodine was in an inorganic form. Okuda and Eto found that the organic iodine compounds were comparatively easily decomposed; moreover, the organic iodine compounds which they discovered were soluble in water, alcohol, dilute acid and dilute alkali solutions.

[2] *Chem. News, 35* (1877), 172-175.

[3] (A) Average of 18 specimens.
(B) Average of 23 specimens.
(C) Average of 5 specimens.
(D) Average of 12 specimens.
(E) Average of 4 specimens.
(F) Average of 8 specimens.

[4] *J. Soc. Chem. Ind., 30* (1916), 565-574.

[5] *z.f. physiol. Chem. 23* (1897), 30.

[6] *J. Coll. Agr., Imp. Univ. Tokyo, 5* (1916), 342-53.

[7] *J. Agr. Soc., 128* (1912), 1.

TABLE 6

COMPOSITION OF DRY MATTER OF SEAWEEDS

	Laminaria digitata Stems average of 15 samples	*Laminaria digitata* Fronds average of 12 samples	*Laminaria stenophylla* Stems average of 8 samples	*Laminaria stenophylla* Fronds average of 8 samples	*Fucus vesiculosus* average 8 samples	*Fucus vesiculosus* average 10 samples	*Fucus serratus* average 8 samples
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Organic matter	64.25	77.99	65.27	77.53	80.10	79.31	78.63
Nitrogen	1.28	1.19	0.98	1.05	0.99	0.98	1.19
Ash soluble in water	28.08	16.92	28.64	17.91	15.62	16.21	15.87
Ash insoluble in water but soluble in dilute HCl	7.08	4.33	5.72	4.37	3.54	4.05	4.51
Siliceous matter	0.59	0.79	0.37	0.19	0.74	0.43	0.99
In soluble ash:							
Potash (K_2O)	10.66	5.19	11.85	4.54	2.94	2.58	3.77
Soda (Na_2O)	5.32	4.06	4.98	5.09	4.25	5.38	4.57
Sulphuric anhydride (SO_3)	2.81	3.00	1.78	2.35	5.47	5.28	3.86
Total halogen as chlorine	10.27	5.88	11.13	6.56	3.24	3.39	4.56
Iodine	0.552	0.329	0.355	0.304	0.034	0.086	0.048

TABLE 7

Composition of Ash of Seaweed

		Ash in weed as received Per cent	Potash (K_2O) in ash Per cent	Iodine in ash Per cent	Lb. iodine per ton of ash Per cent
Laminaria digitata—stems	Maximum	8.19	35.62	2.150	48.16
	Minimum	4.76	20.10	1.056	23.65
	Average (15 samples)	6.09	29.89	1.548	34.68
Laminaria digitata—fronds	Maximum	10.46	26.50	2.729	61.13
	Minimum	3.75	16.80	0.390	8.74
	Average (12 samples)	5.31	23.34	1.697	38.01
Laminaria stenophylla—stems	Maximum	6.15	39.31	1.581	35.41
	Minimum	5.47	27.07	0.594	13.31
	Average (8 samples)	5.75	33.73	1.045	23.41
Laminaria stenophylla—fronds	Maximum	5.25	23.58	1.725	38.64
	Minimum	4.26	16.25	0.958	21.46
	Average (8 samples)	4.72	19.90	1.364	30.55
Fucus nodosus	Maximum	8.02	15.95	1.159	25.96
	Minimum	5.53	9.47	0.217	4.86
	Average (10 samples)	6.19	12.86	0.418	9.36
Fucus vesiculosus	Maximum	9.06	20.82	0.558	12.50
	Minimum	4.66	12.26	0.069	1.55
	Average (10 samples)	6.38	14.95	0.177	3.96
Fucus serratus	Maximum	6.64	20.76	0.300	6.72
	Minimum	4.88	14.31	0.120	2.69
	Average (8 samples)	5.60	17.57	0.220	4.93

Harvesting of the Seaweed.

The kelp burners either cut at ebb tide the rockweeds growing along the seashore or collect the drift-weed that is washed ashore by the waves. The seaweed which is reaped along the shore is called cutweed; it consists chiefly of two sorts of fucus, popularly known as black wrack, or sea oak (*Fucus serratus*) and yellow or bladder wrack (*Fucus nodosus*).

Since the rockweeds are widely scattered along the shores, they are cut by the poorer classes of people living in the vicinity of the beds of seaweed, and the industry has not been organized to any great extent. Most of the "cutweed" is reaped with sickles and scythes when it is exposed at low tide. Inasmuch as it grows on irregular rocks, no machine has been devised for harvesting it. Some of the larger varieties of seaweed are harvested by men in boats who pull the "tangle" from its anchorage in water from 4 to 8 feet in depth. As the seaweed is cut, it is thrown into piles on the shore out of the reach of the tide and later is spread out to dry on the beach.

The drift-weed, often called deep-sea tangle, that is washed upon the shore is collected and spread out to dry. The western coasts of the British Isles are better supplied with drift-weed which is washed up after storms on the Atlantic Ocean. The drift-weed contains much more potash and iodine than the rockweed and it is therefore valued more highly than the rockweed or cutweed. Consequently but little seaweed is now cut; practically all of that burned for iodine and potash consists of tangle or drift-weed.

The seaweeds are dried in much the same manner as hay is dried. They dry rapidly, the time required being necessarily dependent upon the weather. In hot, dry summer weather, they may be burned within forty-eight hours after cutting. A heavy rain on the kelp washes out a large portion of the iodine and potash contained in the weed. So, much care must be taken to prevent loss in this manner. Because of the difficulty of drying the weed in the winter, none is gathered during this season, although more drift-weed is found on the beaches at that time of the year than in the summer and fall. The severe winter storms tear loose much laminaria which is washed up on the beach by the waves.

The Manufacture of Potassium Salts and Iodine from Seaweed.

Incineration Process.

Heap Burning.—In the early days of the European potash industry the ashes of seaweed were obtained by burning the partially dried plants in heaps or piles. The product was called *kelp* in Great Britain and *varec* in France. Even to-day, some seaweed ashes are produced by heap burning of seaweeds. Once started, the fires are kept going by the gradual addition of dried seaweed. The ashes fuse together and form a hard cake. Kelp produced in this fashion always contains more or less foreign matter, such as sand and gravel.

Burning in Kilns.—It is commonly supposed by kelp-burners that a hard product that has been completely fused is desirable. In order to obtain complete combustion of the weed, long, low kilns of rocks are built. These are usually about two and a half feet high and their lengths vary from 8 to 18 feet, depending upon the amount of weed to be burned. Their width is usually about three feet. Brush wood or peat is often burned with the kelp to assist in the combustion.

In burning the seaweed, the kiln is first filled with fuel (firewood, straw or peat) which is kindled. The dried seaweed is then slowly added from time to time. When this has been continued from 6 to 8 hours or all of the dried weed has been added, the porous ash is worked with a rake until all of the weed has burned and the resultant ash is entirely melted. The fused ash from a single burning forms a cake from 3 to 6 inches in thickness on the floor of the kiln. When more weed has been dried, it is burned on top of the kelp cake. Thus a "floor" 15 to 24 inches thick, is built up. This is broken up by throwing water on it while it is hot. It is stored in a dry place until transported to the chemical plants, which manufacture iodine, bromine, potassium sulphate and potassium chloride from it. Table 8 gives analyses by Hendrick[4] of five samples of kelp or seaweed ashes.

The high temperature, required to effect the fusion of the seaweed ash, volatizes much iodine and some potash. Moreover, at the temperature of fusion of the ash, a large portion of the sulphates contained in the kelp are reduced to sulphides, which must subsequently be oxidized to sulphates again.

The Lixiviation and Crystallization Process.

The process by which iodine, bromine and potassium salts are obtained from kelp has been accurately described by Stanford[2] as given below:

> The lixiviation of kelp as at present practised here is a simple process. The kelp is broken up into pieces the size of road metal, and lixiviated in vats coupled and heated by steam, similar to those employed in the lixiviation of black ash; the solution is run off at about 40° to 45° T. This is evaporated in ordinary open boiling-pans (9 feet diameter), and the salts which deposit are fished out. At about 62° T. a rough salt is deposited, consisting of 50 to 60 per cent of potassium sulphate and chloride. The hot liquid is then run into iron coolers, generally cylindrical and of cast iron, and a crop of potassium chloride crystallises out in about three days. The mother liquor is again boiled down three times for good drift kelp, and after each boiling kelp salt is deposited and fished out, and the hot liquor is again run into the coolers, and another crop of potassium chloride obtained. These successive crops will range in strength from 80 per cent to 95 per cent of potassium chloride. The mother liquor, having a density of 85° to 95° T., is then mixed with about one-seventh part of oil of vitriol, 145° T., and allowed to settle for twenty-four hours; the sulphurous compounds are decomposed, and sulphur is precipitated. The liquid is then distilled with peroxide of manganese in an iron still having a leaden cover and two arms; these are connected with two series of stoneware udells, in which the iodine is condensed in hard masses. After the iodine has been driven off, more peroxide of manganese is added, and the leaden arms are connected with another simple condensing apparatus, either of lead or earthenware, and the bromine collected therein.
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> Messrs. Patterson, of this city, who have for some years been the largest makers of iodine, have an excellent method of boiling down by steam, which is used also in some other chemical works here. The liquors are boiled down in large cylindrical wrought-iron vats, heated by a coil of steam piping, and aided by a mechanical

stirrer. This method of boiling is said to effect a saving of fuel and labour, and is more cleanly in use than open pans.

The products obtained are iodine, bromine, "muriate," containing 80 to 95 per cent potassium chloride; "soft sulphate," containing 50 to 65 per cent potassium sulphate; "kelp salt," containing sodium chloride, and 5 to 10 per cent alkali; "kelp waste," containing mostly calcium carbonate and silica, used in the ordinary glass bottle works; and "sulphur waste," containing dry about 70 per cent sulphur. All these products retain iodine, and some require most careful washing to extract it.

TABLE 8

Analyses of Kelp Samples Collected in 1915

	S. Uist Per cent	Benbecula Per cent	Benbecula Per cent	N. Uist Per cent	N. Uist Per cent
Mineral matter soluble in water..	61.66	69.08	70.16	43.59	59.06
Mineral matter insoluble in water but soluble in dilute HCl	24.16	23.55	15.63	40.65	31.12
Siliceous matter	6.64	1.02	8.28	11.23	5.57
Soluble in Water					
Potash (K_2O)	19.24	8.98	10.32	8.97	10.84
Soda (Na_2O)	9.45	15.93	15.02	9.37	10.90
Sulphuric anhydride (SO_3)	9.04	9.79	7.91	5.37	10.49
Sulphur as sulphide	0.24	1.49	0.96	1.33	0.54
Total halogen as chlorine	22.35	27.83	30.36	16.16	20.52
Iodine	1.14	0.58	0.59	0.41	0.37
Lb. iodine per ton	25.63	12.95	13.31	9.20	8.29

The Destructive Distillation of Seaweed.

The time-honored method of producing kelp by the burning of seaweed either in heaps or in kilns is not an economical process, since about half of the iodine contained in the algæ is lost in the burning because of the high temperature developed in fusing the ash. Further, a considerable amount of potash is vaporized. The hot carbon effects the reduction of a considerable proportion of the sulphates to sulphides; these must be oxidized during the crystallization process. Moreover, as the process is ordinarily carried out all the heat produced during the combustion of the dried weed is lost. The seaweeds are gathered only during the spring and summer months, since it is very difficult to dry them at other seasons. This wastes the winter supply of seaweed which consists chiefly of the deep sea algæ. The drift-weed coming in the winter is usually richer in potash and iodine than that at other seasons. Even in the summer, during a wet season, a considerable amount of the salt content of the seaweeds is lost by the leaching of the kelp spread out to dry.

In 1862 Stanford[8] suggested an improved method of producing iodine and potassium salts from seaweed. His process consists in the destructive distillation of the dried seaweed in closed retorts, the collection and utilization of the aqueous, tarry and gaseous distillate, the leaching of the charcoal produced and the working of the resultant liquors for iodine,

[8] *J. Soc. Arts, 10* (1862), 185-195.

bromine and potassium salts according to the usual procedure. By effecting the distillation of the seaweed at a low temperature none of the iodine or potassium salts is lost. The seaweed so treated yields, in addition to the iodine, bromine and potash, an illuminating gas, light and heavy oils, ammonia, acetic acid and charcoal.

According to Stanford's process, the seaweed is collected throughout the entire year, and is dried either in the sun or in sheds. The dried seaweeds are compressed into cakes and charged into gastight iron retorts where the weed is distilled at a low red heat after the manner of the destructive distillation of coal in the production of coke. The distillate is passed through suitable condensers where it is separated into tar, ammonia liquor and illuminating gas. The charcoal is leached with water to obtain a solution of potassium and sodium salts, and then dried. The dried charcoal is used as fuel. The solution containing the sodium and potassium salts, iodides and bromides is evaporated and treated according to the usual procedure in the treatment of kelp liquors.

This process prevents losses of potash and iodine, and produces a solution of potassium salts and iodine free from sulphides. Moreover, valuable by-products are obtained.

However, the equipment required for the destructive distillation of large quantities of bulky seaweed is expensive, and skilled men must be employed to operate it. Moreover, since it is impractical to distil small amounts of seaweed, the weed must be hauled to a central plant, which involves an additional expense.

This process was used on the Island of Tyree and in other parts of the West Highlands for a long period but was finally abandoned. A considerable amount of giant kelp has been distilled in California.

French Iodine Industry.

Importance and Location of Industry.

At present about a fourth of the total quantity of seaweed harvested in Europe is gathered in France. This seaweed is chiefly cut by men in small boats who spread it on the beach to dry. The dried seaweed is burned in shallow pits.

The French seaweed-burning industry is located chiefly along the coast of Normandy in Morbihan, Finistère and Côtes du Nord from Quiberon to Saint-Brieuc. The following places are production centers: Penmarch, Roscoff, Kerlouan, Port-Sall, Pro-poder, the vicinity around l'Abervrack, Quiberon, Laber il Dut, Mollenc, the Beniget Islands, d'Yeu, d'Haedik, Houat, Loctudy and Audierne.

Varieties of Seaweed Utilized on the French Coast.

Of the several hundred species of fuci which are indigenous to the French coast, not more than a dozen are utilized in the manufacture of iodine. The most important of the species utilized include the following: *Fucus vesiculosus, nodosus, siliquosus, serratus, esculentus, thali, alaria,* and *calcut, Laminaria bulbosa, saccharina, digitata,* and *stenophylla,* and *Himanthalia lorea.*

Composition of the French Seaweeds.

Sterkers[9] gives the iodine and water soluble content of the various species of fuci utilized commercially in an interesting article concerning the French iodine industry. His data is presented in Table 9.

Harvesting.

The men who burn the seaweed to produce the fused ash called varec or kelp, either collect the drift-weed from the beach or cut the weed growing along the shore. Many hundreds of small boats are used by those who cut the seaweed. No machinery has been devised for the cutting of the algæ, so it is cut by means of sickle-shaped knives fastened on long poles. The weed rises to the surface as soon as it is cut and is taken into the boats.

Drying and Burning of the Seaweed.

Before the weed can be burned it is dried. This is accomplished in most cases by spreading the seaweed on the beach to dry in the sun, after the manner by which hay is dried. The dried seaweed is burned in shallow pits or low kilns, crudely built of rocks, in much the same fashion as it is burned in Scotland and Norway. The pits are usually about 6 meters long, 0.6 meters wide and 0.4 meters deep. Sterkers[9] gives the average composition of the product (varec) as follows:

Insoluble matter	45.0%
Potassium sulphate	15.0
Potassium chloride	20.0
Sodium chloride	15.5
Potassium and sodium iodides	1.0
Other salts (carbonates, sulphides, and thiosulphates of the alkali metals)	3.5
	100.0%

Manufacture of Iodine and Potassium Salts from Varec.

The Original French Process for the Recovery of Potash and Iodine.—This process of recovery of potassium salts from varec is almost identical to that used in Glasgow which has been described on page 77. However, the iodine is recovered from the mother liquors after the crystallization of the potassium salts in a different manner which is described below.

In the original French process for the recovery of iodine from the kelp liquors, chlorine is used in the precipitation of the iodine. The mother liquors from the crystallization of the potassium chloride (Scotch process described on page 77) are first made slightly acid with sulphuric acid and boiled for some time. The clear liquor is then drawn off from the precipitated sulphur and diluted with water to a density of 1.20 sp. gr. The solution is then saturated with chlorine which precipitates the iodine in a finely divided condition. The clear solution is drawn off and the iodine washed several times to remove the remaining salts. After

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[9] *Rev. Chim. Ind., 25* (1914), 177-188.

TABLE 9

AMOUNT OF ASH AND IODINE CONTAINED IN SEAWEEDS FOUND ON THE FRENCH COAST

Fucus	Amount of seaweed required for 1000 kg. of ash	Soluble matter in 1000 kg. of ash	Iodine in 1000 kg. of seaweed	Iodine in 1000 kg. of ash
Digitatus New leaves	18.752	582	1.224	22.952
(*Laminaria digitata*) Stems	16.988	527	1.089	18.500
Stenolobus Old leaves	16.166	502	0.578	9.344
(*calcut*) "Plantation"	20.095	765	0.606	12.177
Digitatus stenophollus (*taly*) (*Laminaria stenophylla*)	20.255	714	0.996	20.174
Saccharinus (*Laminaria saccharina*)	18.906	711	0.448	8.470
Alaria	21.080	700	0.108	2.227
Vesiculosus *Nodosus* *Serratus* *Siliquosus* Black fuci—average	16.456	507	0.121	1.991
Lorens (*Himanthalia lorea*)	16.401	720	0.087	1.443
Bulbosus (*Laminaria bulbosa*)	21.565	738	0.077	1.660

draining and drying the iodine is sublimed in earthenware retorts. The bromine is sometimes recovered from the liquor, after the extraction of the iodine, by evaporating the solution to dryness, and heating the residue with manganese dioxide and sulphuric acid in lead retorts.

The Modern French Process.—Sterkers has described the modern French process of manufacturing iodine, potassium iodide and other potassium salts from the seaweed ash. This process differs from that in use in Glasgow chiefly in the manner in which the iodine is separated from the liquors. The process is essentially as follows: A saturated solution of the soluble salts contained in the varec is prepared by lixiviating the ash with water. The solution obtained in this manner is neutralized with sulphuric acid which liberates carbon dioxide, hydrogen sulphide, sulphur dioxide and sulphur. When the solution has been freed from these substances, it is treated with copper sulphate. This precipitates the iodine from the solution as cuprous iodide which is filtered off and washed with water. This cuprous iodide is either used for the preparation of iodine or potassium iodide. Iodine is prepared from the cuprous iodide by heating it with manganese dioxide, the iodine subliming off. Potassium iodide is prepared from the copper iodide by heating with an excess of potassium carbonate at about 450°C. The following reaction takes place:

$$2CuI + K_2CO_3 = 2KI + CO_2 + Cu_2O$$

The potassium iodide and excess of potassium carbonate are separated from the insoluble copper oxide by leaching with water. Sulphuric acid is added to the resultant solution to convert the carbonate into the less soluble potassium sulphate, which is separated from the potassium iodide by fractional crystallization.

The solution from which the iodine has been removed as cuprous iodide is worked for potassium salts. It contains in addition to potassium chloride and sulphate, a considerable amount of sodium chloride and a small amount of sodium sulphate. The potassium chloride is separated from the sodium chloride and potassium sulphate by a hot-cold system of fractional crystallization. The iodine manufacturer merely separates the salts into potassium chloride and an impure kainit containing about 50 per cent potassium sulphate, 40 per cent sodium chloride, a little potassium chloride and about 10 per cent of water. According to Sterkers, 1000 kg. of varec gives about 230 kg. of potassium chloride, 350 kg. of impure kainit, 450 kg. of insoluble matter, and 8 kg. of iodine.

Pellieux' Process.—Pellieux and Maze-Launay developed a process for the more complete recovery of iodine and potash from the seaweeds. In order to put their factory on a sound economic basis they operated the year round. To obtain high yields of iodine they collected only the algæ which grow in deep water and neglected the smaller rockweeds. These "deep-sea" algæ contain much larger quantities of iodine and potash than the weeds which are exposed at low tide. In order to operate all the year round it is necessary to dry the algæ indoors. According to their process, the seaweed is allowed to drain for four or five days. It is then thrown on to a water-tight concrete floor where it is permitted to ferment for about forty-eight hours. The drainage water during the fermentation process and the subsequent drying process is caught in tanks and is later evaporated to dryness. This solution contains a considerable proportion of the iodine and potash. The residue after the evaporation is mixed with the partially dried seaweed and the whole burned in a calcining oven. The seaweed ash is worked for potassium salts and iodine according to the procedure ordinarily followed in the manufacture of these substances from varec. By this process there is no loss of potash or iodine during drying as all drainage solutions are collected. Since there is an appreciable loss of iodine through leaching with rain and dew when the algæ are dried in the usual way, this process was designed to prevent these losses and to enable the kelp-burners to utilize the seaweed available during the winter months.

Devillers' Process:—Recently Devillers has developed a process of obtaining iodine from seaweed without incineration. The iodine is removed by washing the seaweed in such a manner as not to remove the carbohydrates. In solution, the iodine behaves as though it were combined as an iodide. It is precipitated from the wash water as Cu_2I_2 in a slightly acid solution. The precipitate is agglomerated by means of gelatin or tannin, after which it is easily separated and dried. The process is in use in the two plants of the Société Industrielle de l'Algue Marine.

Japanese Processes.

Geographical Distribution and Economic Importance of Industry.

Although the Japanese potash and iodine industry did not originate until the latter part of the nineteenth century, it has flourished, and now produces more iodine from seaweed than any other country, being surpassed only by the iodine production of the Chilean nitrate industry. During the World War the Japanese iodine output trebled; doubtless this great increase was partly due to the abnormally high prices of potassium salts and iodine. Japan also produces large amounts of potassium iodide in addition to the production of iodine.

The most important centers of the seaweed-burning industry are Kanaqawa Ken, Chiba Ken and Hokkaido. The iodine refining factories are located in Tokyo and Osaka.

Recently the seaweed-burning industry has become the most important seaweed industry in Japan. In 1916, the production of iodine, potassium iodide and potassium chloride exceeded $3,000,000 in value. The statistics for the Japanese production of iodine and potassium iodide from 1909 to 1917, and for the production of potassium chloride from 1909 to 1916 are given in Table 10:

TABLE 10

JAPANESE PRODUCTION * OF POTASSIUM CHLORIDE, POTASSIUM IODIDE AND IODINE 1909–1917

Year	Potassium Chloride		Potassium Iodide		Iodine	
	Weight lbs.	Value	Weight lbs.	Value	Weight lbs.	Value
1909	1,044,011	$ 19,110.50	153,547	$251,492.00	76,773	$ 121,394.50
1910	1.505,115	24,559.50	156,426	258,790.00	119,190	191,162.00
1911	2,065,528	26,425.00	136,300	238,281.50	117,493	187,338.00
1912	2,287,139	32,515.00	128,138	291,166.50	145,717	283,849.00
1913	4,451,967	53,568.00	158,234	373.650.50	152,566	330,013.00
1914	4,286,822	58,377.50	177,961	428,781.00	239,743	604,603.50
1915	7,440,275	339,419.50	221,334	703,952.50	289,474	784,851.00
1916	16,875,534	1,401,930.00	308,640	817,470.00	657,708	1,497,763.50
1917			222,150		484,138	

* Statistics 1909-1916 are taken from *Far Eastern Review, 14* (1918), 360-1.

Species of Algæ Used.

Iodine exists in small amounts in all algæ, but as has been previously pointed out certain species contain much larger amounts than others. In Hokkaido, the chief genera of algæ utilized for the manufacture of iodine and potash are the laminaria or kelps, which the Japanese call kombu. But on other islands "kajime" (*Ecklonia cava*), "arame" (*Ecklonia bicyclis*) and "ginbaso" (*Sargassum*) are largely collected and burned.

Composition.

The average iodine content in the seaweeds commonly used in Japan for the manufacture of iodine and potash is given in Table 11.

Okuda and Eto[10] conducted extensive investigations relative to the iodine content of certain Japanese seaweeds. A summary of their analytical work is presented in Table 12. They concluded that algæ in an open sea contained more iodine than the same species in an inland sea, and that the iodine content of algæ was least in the spring and highest

[10] ***J. Coll. Agr. Imp. Univ. Tokyo, 5*** **(1916), 341-353.**

TABLE* 11

Analyses of Seaweeds from which Iodine is Extracted

Japanese Name	Scientific Name	Locality	I in 100 parts raw weed	Ash in 100 parts weed	Iodine in 100 parts ash
Kajime	*Ecklonia cava*	Chiba Prefecture	0.232	54.828	0.424
"	" "	Yamaguchi Prefecture	.251	47.223	.531
Arame	*Ecklonia bicyclis*	" "	.271	50.904	.531
Ginbaso	*Sargassum sp.*	" "	.054	52.042	.104
"	" "	Chiba Prefecture	.029	51.941	.057
Kombu	*Laminaria angustata*	Hokkaido	.180	18.686	.990
"	*Laminaria longissima*	"	.173	27.290	.634
"	*Laminaria japonica*	"	.106	17.156	.619
"	*Laminaria ochotensis*	"	.188	20.308	.922

* From Smith, H. M., *Bureau Fisheries Bull. 24* (1904), 162.

in the fall. As mentioned before, this indicates that a single iodine determination on an alga is of little value unless a representative sample is taken and the time and place of collection given. Table 13 gives the composition of young and old stipes and leaves of *Ecklonia cava* from March to September.

Harvesting.

The cutting of the seaweeds is chiefly done by commercial firms who obtain the exclusive privilege of harvesting the seaweed growing along a particular section of the coast. This is accomplished chiefly by cutting the algæ from the holdfast by means of sickles or hook-like knives fastened on the end of long poles which the fishermen operate from small boats. Some seaweed is obtained by dragging weighted hooks attached to ropes behind moving boats.

The concession for the cutting of the algæ does not include the right to gather the large amount of seaweed washed upon the beaches. During stormy seasons much seaweed is washed upon the beaches by the waves. Most of the work of collection of the seaweed from the beaches is done by the women, except after storms when the whole families come to the beaches and pull the seaweed out of the surf. The wet seaweed is spread on the sandy beach above the high tide level and allowed to dry in the sun and wind. If rain threatens, the drying seaweed is again collected into piles and covered with matting for protection.

The Burning of the Seaweed.

Some dried seaweed is ground and used directly as fertilizer in Japan but the bulk of the dried seaweed is burned. This is accomplished by placing it in long piles and slowly burning. Some care is taken to prevent too rapid combustion to prevent loss of iodine. Sometimes it is burnt in a hollow, scooped out in the sand and plastered inside with clay. Some

TABLE 12

FORM OF IODINE IN VARIOUS SEAWEEDS

Algæ	*Sarg. horneri*		*Sarg. enerve*		*Turb. fusiformis*		*Ecklonia cava*		*Ecklonia bicyclis*	
Iodine	In 100 g. of dry matter	Percentage of total I.	In 100 g. of dry matter	Percentage of total I.	In 100 g. of dry matter	Percentage of total I.	In 100 g. of dry matter	Percentage of total I.	In 100 g. of dry matter	Percentage of total I.
Sol. inorganic	0.010	12	0.017	17	0.013	22	0.020	11	0.000	0
Sol. organic	0.053	66	0.067	66	0.030	50	0.150	80	0.130	73
I. in H_2SO_4 ppt. and in residue.	0.018	22	0.017	17	0.017	28	0.017	9	0.048	27
Total I.	0.081	100	0.101	100	0.060	100	0.187	100	0.178	100

TABLE 13

Iodine Content of Young and Old Stipes and Leaves of *Ecklonia cava*

March to September

	March	April	May	June	July	August	September
Young stalk:							
Iodine in 100 parts of material	0.061	0.067	0.093	—	—	—	0.177
Ash in 100 parts of material..	45.42	46.78	44.28	—	—	—	45.63
Iodine in 100 parts of ash....	.134	.144	.209	—	—	—	.388
Young leaf:							
Iodine in 100 parts of material	.063	.060	.084	—	—	—	.143
Ash in 100 parts of material..	47.27	45.75	43.17	—	—	—	48.90
Iodine in 100 parts of ash....	.134	.130	.195	—	—	—	.290
Old stalk:							
Iodine in 100 parts of material	.118	.118	.147	0.255	0.216	0.142	.267
Ash in 100 parts of material..	46.77	44.64	48.76	49.95	42.95	48.30	45.07
Iodine in 100 parts of ash....	.252	.263	.302	.507	.507	.346	.592
Old leaf:							
Iodine in 100 parts of material	.101	.114	.076	.294	.294	.142	.592
Ash in 100 parts of material..	48.42	43.64	45.28	50.16	41.00	54.12	43.89
Iodine in 100 parts of ash....	.209	.261	.167	.586	.717	.262	.528

seaweed is not burned in the open but is charred in specially constructed furnaces from which the supply of air is partially cut off. In Japan the algæ ashes are not fused but are collected as loose ashes into straw bags like those used for rice. The fishermen sell their ashes to the iodine manufacturers.

The ash contains about 10 per cent of potash (K_2O), although occasional samples contain as much as 18 per cent of potash. The iodine content ranges from 0.2-0.6 per cent, although the higher content is seldom attained.

Extraction of the Ash and Recovery of Iodine and Potassium Salts.

The ash is leached with water which dissolves the soluble salts. This solution is evaporated in iron pans over a fire until a mixture of sodium chloride, potassium and sodium sulphates crystallizes. These crystals are fished out and the solution drawn off and allowed to cool when relatively pure potassium chloride crystallizes out. This evaporation and cooling process is repeated until the mother liquor becomes fairly concentrated in iodides. The remaining liquor is then heated in a porcelain still with manganese dioxide and sulphuric acid. The iodine which is driven off is collected; later it is purified by sublimation.

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Chapter 5.

Potash from Kelp—The Pacific Coast Industry.

Introduction.

History of the Utilization of Kelp on the Pacific Coast.—Although seaweed has been utilized as fertilizer and for other purposes in Europe for many centuries, the seaweed on the American Coast has been neglected until recently. Until 1902, the high content of the giant kelps along the Pacific Coast was not suspected. In that year Balch began a study of the composition of these kelps and in 1903 secured patent rights[1] for "processes of extracting potassium chloride from fuci and algæ." Later, he secured several other patents.[2] However, his attempts to interest capitalists in the utilization of kelp on a commercial scale failed and it was not until 1912 that the production of fertilizer and potassium salts from the giant kelp was begun.

The outbreak of the World War forced the users of potash to look for new sources of supply, and kelp was one of the first to attract their attention. The preliminary surveys indicated vast kelp beds extending along the Pacific Coast most of the way from Mexico to Alaska. These immense beds seemed to offer an almost inexhaustible supply of kelp from which the normal requirements of the United States could be supplied. All that remained to be done was to devise economical means for harvesting the kelp and converting it into fertilizer, potassium salts and other valuable products. A tremendous amount of research work was undertaken to solve these problems. Many methods of utilization of kelp were proposed. The methods were of four distinctly different types, viz.: (1) The direct use of the dried kelp, either alone or admixed with other fertilizer materials. (2) The ash from the incineration of kelp was used either for the preparation of potassium and iodine salts or directly as a fertilizer. (3) Large amounts of kelp were destructively distilled and the volatile distillate collected; the residue was leached and separated into carbon and inorganic salts. (4) The most novel process attempted was that which involved the fermentation of the kelp to form acetic acid, the neutralization of this acid with lime and the subsequent conversion of the acetate into acetone. These methods are discussed in detail further on.

The earliest attempts at harvesting were very crude and involved a good deal of manual labor. Men in flat-bottom scows reaped the kelp by hand, using large sickle knives for the operation. Later, steam or gasoline-propelled scows were equipped with a mechanical reaping device and a belt conveyor, which cut the kelp and conveyed it aboard the harvesting vessel.

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[1] U. S. Pat. 747,291 (1903).

[2] U. S. Pat. 771,760 (1904).
U. S. Pat. 794,481 (1905).
U. S. Pat. 825,953 (1906).

As the machinery for harvesting the kelp and the processes for utilizing it improved, the annual quantity harvested increased rapidly during the World War. But as soon as the war was over the production of potash from kelp slowed down immediately. Most of the plants soon closed, and, at the time of this writing, none of the commercial kelp plants on the Pacific Coast is making potash or potassium salts. At the present prices of potash the utilization of kelp does not appear to be profitable.

Species of Kelp Utilized.—A number of different seaweeds and rockweeds occur on the Pacific Coast of the United States. Four of these are commonly called "giant kelps." These are *Macrocystis pyrifera, Nereocystis luetkeana, Pelagophycus porra* and *Alaria fistulosa.* These four brown algæ possess an unusually high content of potassium. The macrocystis occurs to the south of Point Sur in large groves or beds, often several miles in length and from a few yards to several miles in width. The pelagophycus occurs in scattered groups or individuals along the outer edge of the beds of macrocystis. Although the pelagophycus has the highest content of potassium of the four, it is not of commercial importance as it does not occur in sufficient quantities. North of Point Sur, the chief varieties of kelp found in sufficient quantities are the nereocystis and the alaria.

Extent and Geographical Distribution of Kelp Beds.—Although it has been known for a long time that the beds of giant kelp along the Pacific Coast of America were extensive, their approximate size and location were not determined until 1911, 1912, and 1913. In those years the United States Department of Agriculture undertook an extensive survey of the kelp beds. The results of this investigation were published in 1915 by Cameron, Crandall, Rigg, and Frye.[3] Table 14 is a summary of their findings in tabular form. In addition to estimating the area of the kelp groves, the investigators charted the kelp beds, studied the methods of growth of the various kelps, noted the character of the bottom where kelp was found, and considered the availability of harbors for industrial plants. They concluded that there were approximately 390 square miles of kelp beds along the entire Pacific Coast, and estimated that this area would yield 59,500 tons of green kelp annually. This figure has been shown to be entirely too high. The practical results of the harvesting show that only about ten per cent of the estimated amount was actually harvested at a cutting. The amount of harvestable kelp was overestimated in most cases. Shallow water and rocks often interfere with the harvesting. Moreover, it is not economically practical to attempt to harvest all of the kelp. Even at the height of the kelp industry only about one-twentieth of the area surveyed on the Pacific Coast was utilized, or an area of about twenty square miles.

The figures in Table 14 indicate that about half of the area of the kelp beds are in the vicinity of San Diego, California. It was to be expected, therefore, that the greatest area of kelp harvested was in that region

[3] *U. S. Dept. Agr. Rept. 100.*

TABLE 14

SHOWING AREAS AND TONNAGE OF COMMERCIALLY AVAILABLE KELP BEDS OF THE PACIFIC COAST

Region	Area	Fresh Kelp	Potassium Chloride
	sq. mi.	[a] tons	tons
Cedros Island to San Diego	91.36	16,979,800	649,000
San Diego to Point Conception	97.92	18,195,300	696,000
Point Conception to Cape Flattery	36.24	4,377,400	167,000
Puget Sound	5.00	520,000	20,000
Southeast Alaska	70.78	7,833,000	299,000
Southeast Alaska (estimated)	70.78	7,833,000	299,000
Western Alaska	17.86	3,567,000	136,000
	389.94	59,305,500	2,266,000

[a] Two cuttings per annum.

About two-thirds of all the kelp that was cut grew in the vicinity of San Diego, and was utilized in plants near that city.

Importance of Kelp Industry During the World War.—Although the amount of potash obtained from kelp during the war was slight in comparison to the quantity previously imported from Germany, the kelp potash industry was second in importance in the United States. Table 15 gives the amounts of potash produced in the United States during 1917 and 1918. During 1917, a time when there was such a stringent shortage of potassium salts in the United States, 3,572 tons or 7,144,000 pounds of potash (K_2O) were produced from kelp, which represented but a small amount of the total harvestable kelp on the Pacific Coast.

Physiology of the Kelp Plant.

Conditions for Growth.—The principal conditions for growth are the same for any of the giant kelps. They occur only on rocky bottoms where

TABLE 15

POTASH PRODUCED IN THE UNITED STATES[a]

(short tons)

Sources	Number of Producers		Total Production		Available Potash	
	1917	1918	1917	1918	1917	1918
Natural brines	10	27	70,876	149,052	20,652	39,716
Alunite	3	4	7,153	6,180	2,402	2,621
Dust from cement mills	8	12	13,582	12,652	1,621	1,549
Kelp	10	8	11,306	14,029	3,572	4,804
Molasses distillery waste	4	8	8,589	11,792	2,846	3,476
Steffens waste water	5	51	2,642	1,100	369	643
Wood ashes	49	7	1,035	8,243	621	1,213
Other sources	6	9	2,777	3,519	490	529

[a] U. S. Geol. Surv., *Mineral Resources of the United States,* 1917 and 1918.

the holdfasts may be securely anchored. The kelps are chlorophyllous plants of considerable size and require, in the aggregate, a large quantity of carbon dioxide to build up their tissues. Being submerged their only supply of carbon dioxide is that obtained from the sea water. Since sea water contains but little carbon dioxide, there must be a large volume of water brought into contact with the kelp plants. Hence the kelps are found only where there is an ocean current on the open seacoast or in rapid tideways.

While the kelps differ from one another in appearance and in certain characteristics, their anatomy and physiology are much the same. They all have a group of tentacle-like branches called a holdfast which resembles in appearance the roots of a land plant. The holdfast grows about a rock or other fixed object and thus acts as an anchor. A stipe or stem extends from the holdfast towards the surface, terminating in the pneumatocysts or floats, which are hollow organs with thick, fleshy walls filled with gas. The floats tend to hold the kelp on or near the surface. The fronds or leaves extend from the pneumatocysts. The tissues of the kelps contain practically no fiber and therefore are easily crushed to a pulpy mass. The characteristics of the various kelps have been described by Cameron[3] in the report entitled "Potash from kelp."

Macrocystis Pyrifera.—The bulk of the giant kelp that was commercially harvested was *Macrocystis pyrifera.* This kelp, from Point Sur southward, predominates almost to the exclusion of other species. It occurs in large beds, sometimes several miles in length and varying from fifty yards up to two or three miles in width. The plant grows on rocky bottoms free from shifting sand. It is usually found on exposed coasts where there is a continual swell. The larger groves occur at depths of water varying from 6 to 10 fathoms.

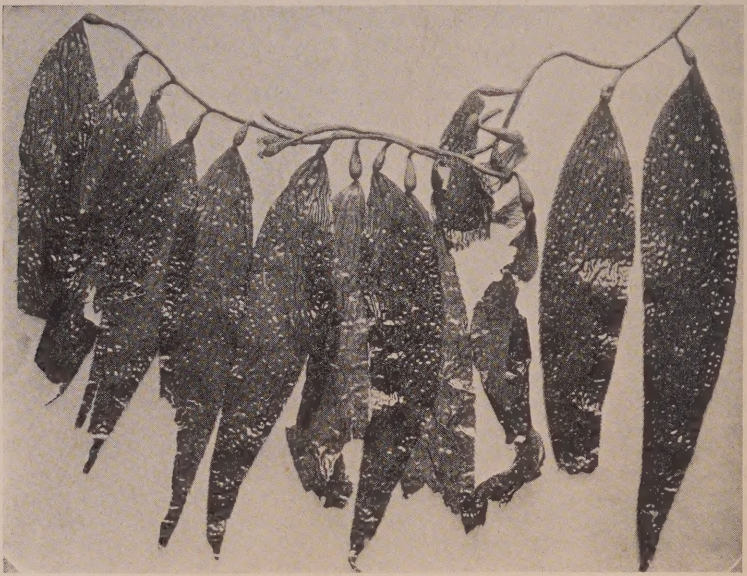
This plant grows from a holdfast sometimes reaching two feet in diameter and attached to rocks on the bottom of the ocean. It grows as a group of stipes which correspond to the stems of plants of higher orders. The stipes vary from one-half inch to three-fourths of an inch in diameter at the base, and from twelve to nearly a hundred in number. Each stipe bears at intervals along its entire length a series of fronds or leaves, each having at its base a small pneumatocyst. The leaves are serrated, are about a foot in length, and about four inches wide. The pneumatocyst is a bulb-like process and is about two inches in length and about an inch in width. The stipes are usually about 100 feet in length although they are often much longer; even a length of 1,000 feet has been reported.

The macrocystis reproduces by means of spores from which new plants spring. The growth of the individual stipes is by means of the splitting of a terminal leaf, the proximal portion of which forms new pneumatocysts and leaves, while the upper portion continues to grow and split until the stipe has reached its maximum length.

Inasmuch as this plant is a perennial and grows rapidly, the beds may be harvested from three to four times each year without danger of exhausting them.

Nereocystis Luetkeana.—Nereocystis is an annual. The plant consists of a holdfast from which stretches a long stipe, that terminates in a large, nearly spherical pneumatocyst or float, which, as the plant matures, separates into a number of long string-like leaves. It propagates by spores formed in spots or sori on the leaves. This plant is less common than the macrocystis and often grows around the outside of the beds of macrocystis. North of Point Sur, however, there are large beds of pure stands of this kelp.

Alaria Fistulosa.—Alaria is a perennial plant found in the tideways of the Alaskan coast. Its holdfast is quite similar to those of other kelps, from which grows a stipe about 8 inches in length, at the extremity of which grows a bunch of relatively small leaves which are the spore producers. From the bunch of leaves extends a long leaf averaging about 40 feet in length. Its average width is less than 20 inches, although wider leaves are often found, some of which have a width of five feet. A hollow, flat midrib, perhaps an inch in diameter, extends throughout the length of the leaf. The midrib contains nodes at intervals of a few inches, so that the whole midrib is a series of floats. The outer part of the leaves is usually more or less torn; this feature gives the plant the local name of "stringy kelp."



Courtesy Bureau of Soils.

FIG. 28.—Macrocystis Pyrifera, the commercial kelp of the Southern California waters.

The Composition of the Giant Kelps.

Inorganic Constituents.—Since potassium salts and iodides are the valuable inorganic constituents of kelp, most of the analyses of kelp ash give only the percentage content of these substances. Parker and Lindemuth[5] analyzed 16 samples of *Nereocystis luetkeana*, and 23 samples of *Macrocystis pyrifera*, collected at various points along the Pacific Coast. They found that the nereocystis ranged from 16.20 per cent to 31.62 per cent of potash (K_2O). The potash content of macrocystis was found to be even more variable, ranging from 3.20 per cent to 27.66 per cent of potash (K_2O). The iodine content of nereocystis varied from 0.13 per cent to 0.30 per cent, whereas, the iodine content of macrocystis ranged from 0.14 per cent to 0.27 per cent.

Merz[6] has accounted for much of the variation in the analyses of kelp by showing that the stipes of nereocystis and macrocystis were relatively much higher in potash than the leaves. Thus the proportion of stipes to leaves in the sample of kelp taken for analysis has much to do with the result obtained.

The average analysis of fifteen samples of dried *Alaria fistulosa* made by the Bureau of Soils[3] is as follows:

Total soluble salts	24.4%
Potash (K_2O)	9.1
Iodine (I)	trace
Ash	7.5

The variation in content of potash of these 15 samples is from 2.9 per cent to 13.1 per cent.

Riggs[7] has calculated the amounts of potassium chloride, iodine, algin, etc., in a ton of the giant kelps from the data given by Cameron, Frye and Rigg,[3] Hoagland,[8] and Turrentine.[9] His figures are given in Table 16.

TABLE 16

CONTENT OF A TON OF THE VARIOUS KELPS.

	Water	Potassium Chloride	Other Salts	Iodine	Algin	Crude Fiber	Nitrogen
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Nereocystis luetkeana	1834	53.7	25.1 to 37.7	0.22	23.4	8.4	2.9
Macrocystis pyrifera	1736	52.5	26.7 to 55.7	0.61	44.4	19.3	4.3
Alaria fistulosa	1726	39.3	27.6	Trace	No data given	No data given	7.1

These figures indicate the large amounts of kelp which must be handled in order to obtain a ton of potassium chloride.

The Composition of the Organic Matter Contained in Kelp.—Little was known concerning the organic constituents of the Pacific Coast kelps until recently. Various investigators in the California Experiment Station made many analyses to determine whether or not these constituents were of commercial importance. Hoagland[8] reported the analytical results of this work in an interesting paper entitled "Organic Constituents of Pacific Coast Kelps." Detailed analyses of the following species of kelp are given in his paper: *Macrocystis pyrifera, Pelagophycus porra, Egregia lævigata, Egregia menziesii, Laminaria andersonii, Iridæa sp.* These analyses indicate that the major portion of the total organic matter is insoluble in water and in alcohol. Starch and soluble reducing sugars were not found to be present; but pentosans were present in all cases. The total organic matter varies from one-third to three-fourths of the dry weight. The protein content ($N \times 6.25$) varied 2.6 per cent to 17.2 per cent. In only one case was there more than one per cent of ether extract (fat) found. Table 17 gives a summary of Hoagland's proximate analyses.

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[5] *J. Ind. Eng. Chem., 5* (1913), 287-9.
[6] *J. Ind. Eng. Chem., 6* (1914), 19-20.
[7] *J. Ind. Eng. Chem., 8* (1916), 568.
[8] *J. Agr. Res., 4* (1915), 39-58.
[9] *Sen. Doc. 190,* 62nd Congress, 2nd Sess. (1912), 232-262.

Carbohydrates or analogous compounds make up the principal portion of the organic matter. The carbohydrates of these algæ are complex colloidal substances called vegetable gums or pectins. Complex mucilaginous polysaccharids are characteristics of marine algæ.[10] Even where starch and simple carbohydrates have been found in marine algæ, the amounts are relatively small.

The percentage of algin found by Hoagland varied from 13 to 24, calculated on the dry kelp; with the exception of *Iridæa sp.* This alga is a rockweed and possesses properties varying greatly from the other kelps. The crude fiber (chiefly cellulose) content of the kelps was only 3 to 4 per cent calculated on the whole dry plant.

The total sulphur found in the dried Pacific Coast kelp varied from 0.45 to 8.16 per cent; which was approximately half inorganic sulphur and half organic sulphur. Hoagland found from 0.1 to 0.2 per cent of iodine which he believes is present as inorganic iodine and chiefly as iodide. Small amounts of bromine were found in the kelps, but only in one-fifth to one-tenth the quantity of iodine.

Composition of the Gas in the Floater of Kelp.—The giant kelps are kept afloat both by the action of the tidal currents and the gas contained in the floaters. Zeller and Neikirk[11] reported that this gas was a mixture of carbon dioxide, nitrogen and oxygen. Langdon[12] succeeded in separating the gaseous residue after absorption of oxygen and carbon dioxide, which Zeller and Neikirk assumed to be nitrogen and proved that the gas in the floaters contained from 1 to 12 per cent of carbon monoxide.

Commercial Utilization of Kelp on the Pacific Coast.

The Harvesting Process.—The earliest attempts at harvesting and utilization of kelp were very crude. The kelp was reaped by hand with large scythes from scows. Some drift kelp was collected from the beach. The kelp was dried either on the beach or on frames. The partially dried kelp was either chopped and sold as a direct fertilizer or burned on open

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[10] Euler-Chelpin. H. K. A. S. von, Grundlagen und Ergebnisse der Pflanzenchemie. Braunschweig, 1908.

[11] *Puget Sound Marine Sta. Pub.*, *1* (1915), 25-30.

[12] *J. Am. Chem. Soc.*, *39* (1917), 149-156.

TABLE 17

Average Composition of the Organic Matter of Pacific Coast Kelp, Calculated on Whole Plant

Material used	Number of samples analyzed	Percentage composition calculated to fresh material									Percentage composition calculated to a water free basis							
		Moisture	Total salts	Total organic matter	Nitrogen × 6.25	Ether extract	Crude fiber	Pentosans	Water soluble alcohol precipitate	Sodium carbonate soluble acid precipitate (algin)	Total salts	Total organic matter	Nitrogen × 6.25	Ether extract	Crude fiber	Pentosans	Water soluble alcohol precipitate	Sodium carbonate soluble acid precipitate (algin)
Macrocystis pyrifera, harvestable portion, San Diego	8	86.3	5.24	8.45	1.02	0.046	0.98	1.06	0.91	2.56	38.2	61.7	7.4	0.34	7.2	7.7	6.6	18.7
Macrocystis pyrifera, harvestable portion, Pacific Grove	4	87.7	5.28	7.00	1.65	.049	.93	.77	1.07	1.77	42.9	56.9	13.4	0.40	7.6	6.3	8.9	14.4
Macrocystis pyrifera, nonharvestable portion, San Diego	8	87.7	5.16	7.11	1.33	.054	.89	.98	1.08	2.15	42.0	57.8	10.8	.44	7.2	8.0	8.8	17.5
Nereocystis luetkeana, entire plant, Pacific Grove	4	91.7	4.52	3.74	.90	.088	.42	.53	.71	1.17	54.5	45.1	10.8	1.06	5.1	6.4	8.6	14.1
Pelagophycus porra, entire plant, San Diego	2	89.7	5.43	4.91	.77	.028	.64	.87	.61	1.66	52.7	47.7	7.5	.27	6.2	8.4	5.8	16.1
Egregia lævigata, entire plant, San Diego	2	83.7	5.78	10.52	1.89	.144	1.47	1.60	1.48	3.04	35.5	64.5	11.6	.88	9.0	9.8	9.1	18.7
Egregia menziesii, entire plant, Pacific Grove	3	83.6	5.48	10.88	2.82	.110	1.43	1.48	.90	3.14	33.4	66.3	17.2	.67	8.7	9.0	5.5	19.1
Laminaria andersonii, entire plant	1	78.5	5.70	15.80	3.22	.140	2.24	2.15	.37	4.90	26.5	73.5	15.0	.65	10.4	10.0	1.7	22.8
Iridæa sp., entire plant..........	1	80.1	6.25	13.70	3.38	.087	2.09	.18	.26	0.20	31.4	68.8	17.0	.44	10.5	0.9	1.3	1.0

hearths to obtain the ash. This material was afterward used for fertilizer.

Large scale production brought modern engineering practice into use in the harvesting and utilization of kelp. The cost of harvesting kelp is one of the largest items in the cost of production of potash from kelp. The data concerning the composition of green kelp, which have been previously given, indicate that raw kelp contains about 90 per cent of water. This means that ten tons of green kelp must be harvested in order to obtain one ton of dried kelp.

Various types of harvesting equipment were tried out during the growth of the industry. The only cutting device that was found satisfactory operated on the principle of the ordinary hay mowing machine. This machine consists essentially of a number of triangular knives mounted on a horizontal cutter bar, which oscillates on a rigid guard bar through a channel in the guards. Most kelp harvesting machines had similar cutter bars mounted vertically at either end of the horizontal bar. Immediately behind the cutting mechanism a conveyor was placed in such a position that it carried the kelp into the harvester.

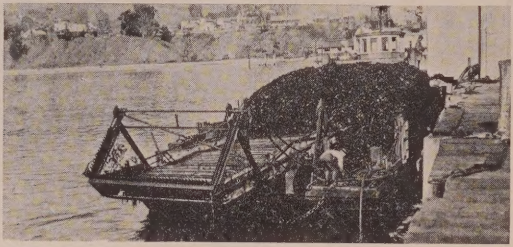

Photo by J. W. Turrentine.

FIG. 29.—Harvester loaded with kelp. U. S. Experimental Kelp Potash Plant, Summerland, Cal.

Thompson[13] described the harvesters of the Lorned Manufacturing Company in the following manner:

> The cutting apparatus consists of a horizontal cutter bar equipped with oscillating knives similar to an ordinary mower. At the end of this horizontal cutter bar, which is 12 feet long, are two vertical cutter bars 4 feet long, equipped with the same kind of knives. The cutter is lowered into the water so that the horizontal cutter bar is approximately 4 feet below the surface, and as the kelp is cut it is carried up and deposited on the deck by a draper or slat conveyor. As the kelp accumulates in the bow of the boat under the draper, it is hauled back by means of a grab-hook operated by a winch, so that the load is kept properly distributed as fast as it accumulates. This harvester carries a crew of six men—a captain, engineer, winchman, cutterman and two hookmen. This is a seaworthy boat and can operate in fairly rough weather. It has a speed of nine miles an hour, and in thick kelp can harvest fifty tons an hour.
>
> On returning, the loaded harvester docks alongside the unloading pier underneath a telpher track extending out from above a receiving hopper. A grab-hook, built like a clam-shell bucket, having a capacity of about 1500 pounds of kelp at a grab, unloads the barge, all lines being handled from a double-drum electric hoist. The unloading is done by an unloading crew of three men. About 30 tons an hour are unloaded in this way.

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[13] *Met. Chem. Eng., 19* (1918), 450-452.

The harvester used by the various companies engaged in the utilization of kelp differed chiefly in size and depth at which they cut the kelp. The depth at which the cutter bar operated varied from four to six feet. Some harvesters remained at sea continually, unloading their contents into barges from time to time. The barges were towed by tug boats to the wharves.

The Hercules Powder Company, which harvested more kelp than any other concern, reduced the kelp to a fine state of subdivision on board the harvester. This permitted the pumping of the kelp from the barge. This company used very large seaworthy harvesters which cut the kelp, in the manner just described, at a depth of about six feet and carried it up out of the water by means of moving screens. From the screens it passed through macerators and thence into the hold of the harvester vessel. Later it was pumped through a pipe boom into a barge, which was towed to the docks where it was pumped directly into the fermentation tanks.

Since a large portion of the kelp lies on the surface of the water in lengths varying from 5 to 75 feet, the proportion of each plant cut is approximately fifty per cent. The balance of the plant probably dies, rots, and is lost. However, new stipes usually grow from the holdfast so that in a few months the kelp bed may be harvested again.

The Value of Kelp as Feed.—The extensive use in Japan and Hawaii of certain seaweeds as food suggested the possible use of the giant kelps as stock feed. Hoagland[8] investigated this possibility and found that the carbohydrates contained in kelp were very difficult to digest and were of little nutritive value except when eaten by animals of the ruminant type. The enzymes of the digestive tract are unable to hydrolyze them directly. Hoagland concludes that "these resistant carbohydrates are at best of low rank among feeding materials."

Kelp as a Direct Fertilizer.

Methods of Preparation—Chopping Without Drying.—One of the first companies to attempt the utilization of the Pacific Coast kelp was the Pacific Kelp Mulch Company. This company operated a plant for several months at Terminal Island, California. Their process was the simplest possible, as it involved merely the chopping of the kelp into small pieces, sacking the product and selling it as fertilizer. Their product contained nearly 90 per cent of water and thus an immense amount of water was shipped. Such a process could succeed only when the kelp was used in the immediate vicinity of the beds, so that the transportation charges would be small.

The Preparation of Dried Kelp.—Since there is but little rainfall along the coast of Southern California where the kelp industry came into existence, the early experimenters tried to dry kelp by the heat of the sun. This never worked on a commercial scale, due to the mechanical difficulties involved in keeping fresh surfaces exposed to the drying currents of air. Kelp is difficult to dry because of its high content of salts and because of the jelly-like nature of its juice which on drying forms a protecting envelope over the surface.

It is possible to squeeze out a large proportion of the juice mechanically.

TABLE 18

FORMS OF NITROGEN IN KELP

No.	Material Used	Percentage of Dried and Ground Sample					Percentage			
		Total nitrogen	Non-protein Nitrogen		Water soluble nitrogen	Alcohol soluble nitrogen	Non-protein Nitrogen		Water soluble nitrogen	Alcohol soluble nitrogen
			By Stutzer's reagent	By phospho-tungstic acid			By Stutzer's reagent	By phospho-tungstic acid		
1.1	*Macrocystis pyrifera* No. 1, harvestable leaves	1.69	0.55	0.42	0.58	0.18	32.5	24.9	34.3	10.7
1.2	*Macrocystis pyrifera* No. 1, harvestable leaves	.98	.30	.32	.38	.12	30.6	32.7	38.8	12.2
1.3	*Macrocystic pyrifera* No. 1, nonharvestable leaves	2.40	.89	.70	.99	.32	37.1	29.2	41.2	13.3
9.1	*Macrocystis pyrifera* No. 9, harvestable leaves	1.01	.19	.18	.20	.06	18.8	17.8	19.8	6.0
9.3	*Macrocystis pyrifera* No. 9, nonharvestable leaves	1.62	.32	.25	.41	.10	19.8	15.4	25.3	6.2
15.1	*Pelagophycus porra* No. 4, leaves	1.24	.22	.18	.23	.18	17.7	14.5	18.5	14.5
15.2	*Pelagophycus porra* No. 4, harvestable stem	.98	.15	.16	.23	.07	15.3	16.3	23.5	7.1
27.1	*Nereocystis luetkeana* No. 1, leaves	1.86	.50	.37	.52	.35	26.9	19.9	28.0	18.8
28.1	*Nereocystis luetkeana* No. 2, leaves	1.90	.55	.48	.58	.43	29.0	25.3	30.5	22.6
29.1	*Nereocystis luetkeana* No. 3, leaves	2.20	.65	.57	.73	.47	29.5	25.9	33.2	21.3
29.2	*Nereocystis luetkeana* No. 3, stem	1.05	.24	.21	.28	.15	22.9	20.0	26.7	14.3
30.1	*Nereocystis luetkeana* No. 4, leaves	1.97	.48	.45	.55	.32	24.4	22.8	27.9	16.2
42.	*Egregia menziesii* No. 3, complete strands	2.75	.43	.37	.48	.24	15.6	13.5	17.5	8.7
43.	*Laminaria andersonii*, entire plants	2.38	.48	.41	.65	.32	20.2	17.2	27.3	13.4
44.	*Iridæa sp.*, entire plants	2.67	.52	.53	.58	.36	19.5	19.8	21.7	13.5

Since this juice varies only slightly in potash content from the kelp itself, nothing is gained by the operation.

All large-scale plants have resorted to horizontal driers to dry the shredded kelp. The direct-heat rotary drier appears to be the most satisfactory type of drier. Since the kelp leaves are thin and present a great surface in proportion to their weight while the stems are thick and fleshy, it is necessary to reduce the kelp to pieces of uniform size before being fed to the rotary drier. If the whole kelp plants are fed to a drier, the leaves are quickly dried, while the stems come through very wet. If, however, the kelp is shredded, the drying is uniform.

Fuel oil was used in southern California as the source of heat for drying. In the Puget Sound region, shredded waste wood was burned for fuel.

The length and number of driers used in drying the kelp depend upon the temperature and speed with which the kelp passes through. Some plants used but one highly heated drier. Others took precautions to prevent the charring of the kelp in the drier, and used one long drier or two shorter ones.

The average size of the driers used was fifty feet long and five feet in diameter. The capacity of such a drier depends upon the temperature and humidity of the air passing through it. but their average capacity was about four tons of green kelp per hour. Only those at the Experimental Kelp Potash Plant of the United States Department of Agriculture were built to operate countercurrentwise, hot air being blown in at one end and raw kelp fed into the other. All other driers were operated concurrent-wise.

In some factories the dried shredded kelp was mixed with other fertilizer materials without grinding; in others, it was ground before it was shipped.

Dried Kelp as a Fertilizer.—Dried kelp contains about fifteen per cent of potash (K_2O), which is present chiefly as potassium chloride, and about two per cent of nitrogen. In addition to these two fertilizer constituents, the kelp contains a large amount of organic material which slowly decays in the soil, forming humus. About 95 per cent of the potash contained in the dried kelp is easily leached out, so this is readily available without further treatment.

The nitrogen of the dried kelp becomes slowly available after application to the soil. Skinner and Jackson[14] found that dried kelp gave an increased crop of about 23 per cent as compared with 22 per cent when potassium chloride was used. Cullen[15] concluded that the official alkaline permanganate method is not suited for determining the available nitrogen in kelp; and, further, that if a sufficient amount of potassium permanganate was used to oxidize all the organic matter present, all, or nearly all of the nitrogen is found to be available. Christie[16] reports that dried and ground kelp decomposes in the soil under laboratory conditions increasing the humus content to an extent comparable with alfalfa, manure and straw.

[14] *U. S. Dept. Agr., Bur. Soils Circ. 76* (1913).
[15] *J. Ind. Eng. Chem., 6* (1914), 581-2.
[16] *J. Ind. Eng. Chem., 8* (1916), 425-7.

Stewart[17] conducted many detailed experiments to determine the available nitrogen in dried kelp. He found that *Macrocystis pyrifera,* the most important commercial kelp, is very slowly changed in the soil.

Stewart's other conclusions are given below:

> In preparing dried and ground kelp as a fertilizer the availability or readiness with which the nitrogen in it is changed to ammonia and nitrates in fresh field soil was found to vary with the different species and the manner of preparation.
>
> The nitrogen of *Nereocystis luetkeana* is relatively very available while that of *Pelagophycus porra* is less readily changed. These two varieties are of minor importance.
>
> The availability of *M. pyrifera* is greatest when the kelp is in a fresh or only partially dried condition.
>
> The availability of its nitrogen decreases materially when macrocystis is fully dried.
>
> Removing a large portion of the salts from either fresh or dry macrocystis does not cause it to decompose more readily.
>
> Macrocystis must be dried until crisp in order to grind readily. This drying should not be continued longer than necessary and the kelp should not be scorched or overheated.
>
> The addition of moderate quantities of nereocystis to a sample of fresh soil in the laboratory did not cause any great interference with either ammonification or nitrification of readily available organic matter such as dried blood.
>
> Similar experiments with macrocystis showed at first a decrease in the rate of transformation especially in nitrification. This decrease did not continue and as time went on the ammonification and nitrification became practically normal.
>
> When using kelp in field practice, it is probable there would be no interference with either ammonification or nitrification from either the kelp or the salts present in it.

The Recovery of Potash by Incineration of Kelp.

The earliest attempts at the utilization of kelp were rather crude. The kelp was spread thinly upon the beach or on low-lying land near at hand and allowed to dry. The dried kelp was raked together and burned.

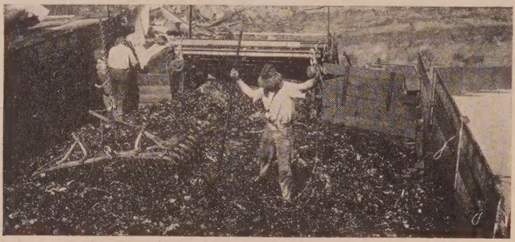

FIG. 30.—Unloading kelp at Lorned Manufacturing Company's plant, Long Beach, Cal.

The ashes were sold to fertilizer companies at a price based on their potash (K_2O) content which usually was about 15 per cent. The larger companies which produced kelp ash dried the chopped kelp in horizontal, rotary, direct-heat driers which burned crude oil. The dried kelp usually was burned in rotary cylindrical incinerators or in reverberatory furnaces. Some plants leached the ashes and separated the sodium chloride and potassium chloride by fractional crystallization. By this process nearly pure potassium chloride was obtained.

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[17] *J. Agr. Res., 4* (1915), 21-38.

The process used in the kelp-potash plant of the Lorned Manufacturing Company[18] involved a partial incineration of the dried kelp. As the kelp was unloaded from the harvester it was dumped into a hopper which fed a chopper. The chopper cut the kelp into lengths averaging about 12 inches. The chopped kelp dropped into a drag conveyor which emptied the kelp into a 300-ton storage bin. The V-shaped bottom of the storage bin was arranged so that the kelp was slowly emptied on to a conveyor leading to a "tilting box feeder" which alternately emptied its contents into first one horizontal revolving drier and then the other. The moisture content of the kelp was reduced from 90 per cent to approximately 25 per cent in these driers. The partially dried kelp then passed to the incinerators. These were merely rotary kilns 40 feet long and 5 feet in diameter, similar in construction to the driers, except that they had no furnace or oven, the oil flame shooting directly into the drum. In this incinerator the flame completed the drying of the kelp and burned off the volatile hydrocarbons, producing a gray charcoal containing about 35 per

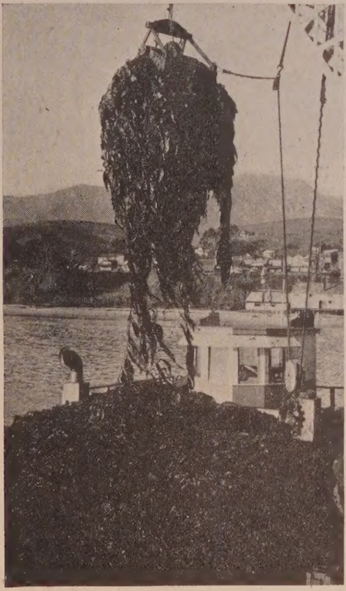


Photo by J. W. Turrentine.

Fig. 31.—Unloading kelp at U. S. Experimental Kelp Potash Plant, Summerland, Cal.

cent potash (K_2O). This charcoal was cooled, ground and sacked for shipment to the fertilizer factories.

If the kelp ash is to be used as fertilizer there is little to be gained in burning it as the organic matter is destroyed in obtaining the more concentrated product. Obviously, no by-products are obtained so potash can be produced economically by this method only when the price is high.

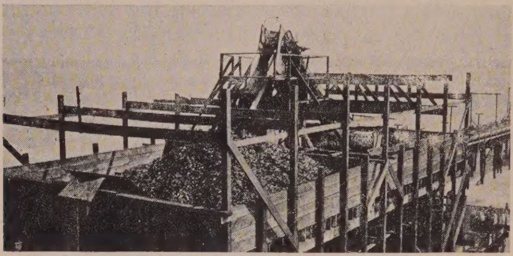


Photo by J. W. Turrentine.

FIG. 32.—Wet kelp storage bin at U. S. Experimental Kelp Potash Plant, Summerland, Cal.

The Destructive Distillation of Dry Kelp.

The destructive distillation of seaweeds was suggested first by E. C. C. Stanford in 1862. He suggested this method to prevent losses of potash and iodine. Stanford reported that he obtained ammonia, acetone, wood alcohol, a light volatile oil, a coloring matter, tar, and combustible gases. After the distillation process has been completed, the residual charcoal must be leached with water to obtain the potash and iodine salts.

Balch was the first person in the United States to propose the destructive distillation of the giant kelps. He patented[1] a process for distilling kelp in a closed retort. Balch dried the kelp in the sun, then ground the dry kelp and lightly compressed it in a retort. A small amount of lime or other alkaline substance was sprinkled over the kelp before the heating was commenced. He heated the kelp to a temperature "sufficiently high to completely decompose the organic portion of the seaweed, but not high enough to break up the sulphates present." He collected the volatile products of the distillation in condensers, and lixiviated the char, obtaining a porous charcoal, and by the evaporation of the solution produced potassium chloride.

The Fertilizer Division of the Bureau of Soils, U. S. Department of Agriculture, has conducted many researches both on a laboratory and on a commercial plant scale, to demonstrate the value of the distillation process of utilizing kelp. These experiments have covered a period of ten years. J. W. Turrentine devised a method for the continuous and automatic distillation of kelp in vertical retorts, an adaptation of the principle of the vertical coke oven. Small scale tests of this method were followed by the installation of a full plant scale equipment of retorts, and the method has been applied with entire success. The same advantages are found in this method of reducing kelp to a charcoal as are found in by-product coking.

To make possible a commercial demonstration of the distillation process Congress authorized the erection of the Experimental Kelp Potash Plant, by the Bureau of Soils, at Summerland, California. Construction was commenced in March of 1917, the plant was put into operation in August of that year and was operated continuously until the spring of 1921. During this period a complete process was developed and installed for rendering from the raw kelp a series of refined products including kelpchar, a highly active decolorizing carbon; potash salts; iodine; ammonia; kelp oils, and creosote.

With the completion of this demonstration, the plant was sold to a private corporation.

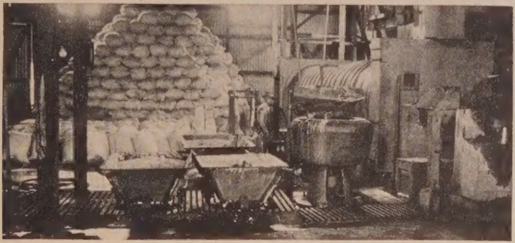


Photo by J. W. Turrentine.

FIG. 33.—View in potash room at U. S. Experimental Kelp Potash Plant, Summerland, Cal.

The results in the form of processes and products of the Experimental Plant have been described by the various members of the chemical staff in a series of journal articles.[18] The chopped kelp is passed through two direct-heat counter-current, revolving, horizontal, hot-air driers which are heated by means of oil burners. The dried kelp is distilled in vertical, fire-clay retorts, enclosed in a vertical furnace built on a steel platform, and are heated with hot air from small furnaces adjoining.

A temperature of about 800° C. is maintained in the flues surrounding the retorts. The kelp fed into the top gradually works downward as it shrinks in volume. The volatile products are drawn off at the top of the retorts. After passing the hottest zone of the retort the char is discharged gradually into the small hopper, constituting the bottom of each retort, where it partially cools. At regular intervals it is removed, cooled and ground.

[18] Turrentine, J. W., and Shoaff, P. S., *J. Ind. Eng. Chem.*, *11* (1919), 864.
Spencer, G. C., *ibid.*, *12* (1920), 682.
———, *ibid.*, *12* (1920), 786.
Turrentine, J. W., and Shoaff, P. S., *ibid.*, *13* (1921), 605.
Turrentine, J. W., and Tanner, H. G., *ibid.*, *14* (1922), 19.
Tanner, H. G., *ibid.*, *14* (1922), 441.
Turrentine, J. W., Tanner, H. G., and Shoaff, P. S., *ibid.*, *15* (1923), 159.

The gas evolved during the distillation is passed into small cyclone condensers, which are attached to the top of each retort. Here the less volatile tar is separated. Then the four streams of gas are led collectively into the bottom of a vertical sheet iron condenser; here the remaining tarry constituents and the aqueous distillate are separated from the gas, which may then be burned. The condensate separates into two layers in the vertical condensers, one of oils and one of ammonia liquor. The products obtained from the condensers are tar, from which are separated oils valuable for flotation work, creosote of high phenol coefficient, and pitch; an aqueous distillate containing ammonia, an unidentified liquid having many physical properties of glycerol, and various other substances.

The potash is extracted from the kelp charcoal with water by a continuous counter-current leaching process. The charcoal is extracted further successively with hot hydrochloric acid and water. The product is an excellent decolorizing carbon, which possesses a high degree of activity and has been successfully marketed under the name of kelpchar.

After the elimination of the sulphate, the brine resulting from the leaching of the charcoal contains only the chlorides of sodium and potassium. These are separated by the so-called hot-cold method of fractional crystallization. Vacuum evaporators and vacuum crystallizers are used for the concentration of the solution and the crystallization of the salts. The crystallization is continued until the mother liquor becomes sufficiently concentrated in salts of iodine, when it is withdrawn for storage. Later it is utilized in the preparation of iodine.

The operations of the plant and the products yielded are represented graphically by the flow sheet, Fig. 34.

Commercial Fermentation of Kelp.

During the World War the shortage of calcium acetate and its solvent derivatives was acute. There was a tremendous increase in the demand for acetone, acetic acid and acetic anhydride. Large quantities of acetone were used as a solvent in the manufacture of smokeless powders and in preparing dopes for airplanes. The Hercules Powder Company was one of the first large companies to feel the shortage keenly. They attempted to fill their own needs by manufacturing acetone and calcium acetate from kelp. Their process was unique in that the primary products were organic solvents; potassium salts and iodine were obtained as valuable by-products.

Very little experimental work on the manufacture of organic products from kelp had been carried out prior to the researches of the Hercules Powder Company. Stenhouse[19] in 1851 produced calcium acetate by the fermentation of kelp. This research is the only one known to have been carried out along this line.

After conducting extensive investigations on the manufacture of calcium acetate and other products from kelp, the Hercules Powder Company erected a very large plant for the production of calcium acetate, potassium salts, iodine, etc., by the fermentation process. This plant was located on the bay at Potash, near San Diego. Its cost was in the neighborhood of $2,000,000. This plant alone utilized about 24,000 tons of kelp a month.

[19] *Philos. Mag. and J. of Sci.* (Ser. 4) *1* (1851), 24-26.

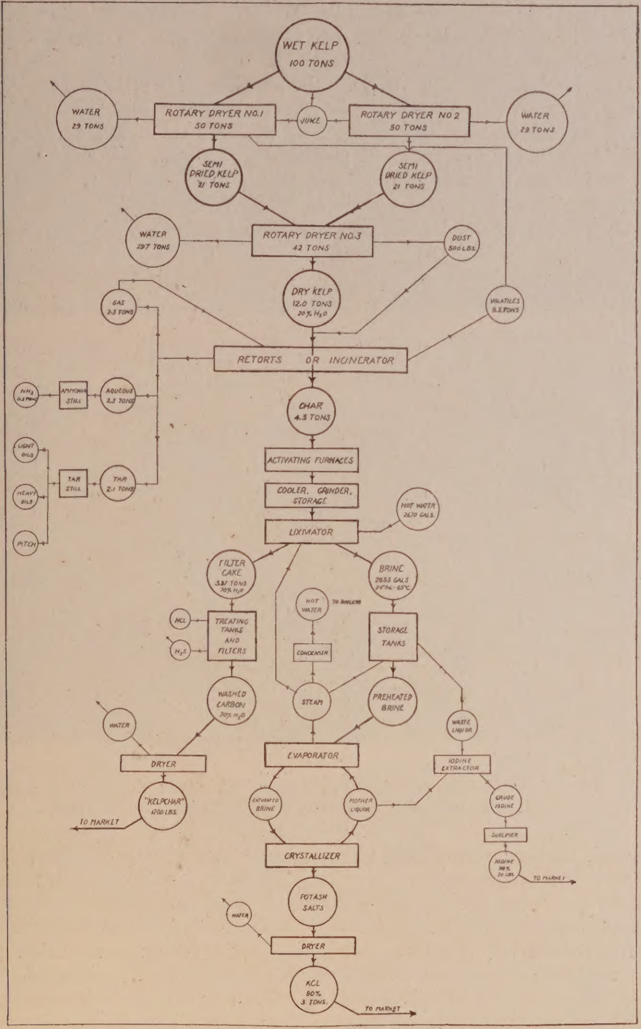
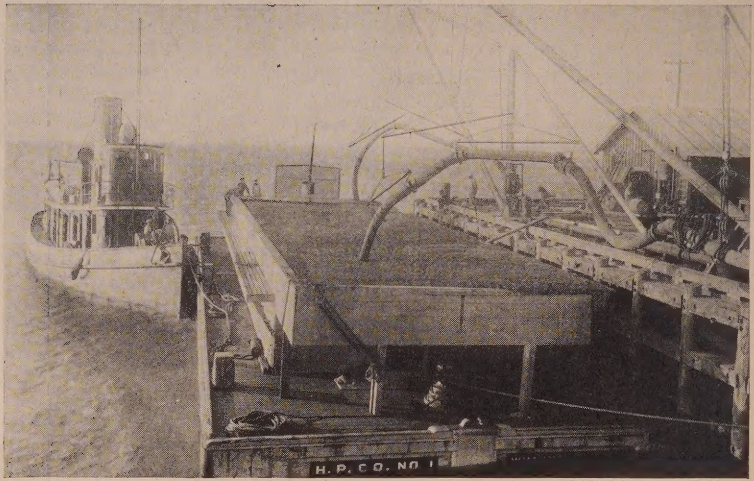


FIG. 34.—Flow sheet showing products obtained by the destructive distillation of kelp at the U. S. Experimental Kelp Potash Plant, Summerland, Cal.

General Operations of the Hercules Powder Company's Plant.

The operations of the Hercules Powder Company's plant have been described in considerable detail by Higgins[20] and in Metallurgical and Chemical Engineering.[21]

Large harvesters were used in the cutting of the kelp; the harvested kelp was macerated on board the harvester before it was transferred to the barges. This permitted the transfer of the kelp by means of Gould rotary pumps. When the kelp arrived at the plant, it was pumped to large redwood tanks where it was diluted and allowed to ferment under the proper temperature conditions and hydrogen ion concentration. About 150 large tanks were required to hold the enormous quantity of kelp which was harvested. These tanks held about 50,000 gallons each. Each tank was equipped with hot water coils for temperature regulation and compressed-air pipes provided the proper agitation. The required degree of acidity was maintained by the neutralization with calcium carbonate of the excess acid formed during the fermentation. During the fermentation process, which required about two weeks, organic acids (acetic, propionic, butyric, valeric, etc.) were formed, which upon neutralization with calcium carbonate, formed the corresponding calcium salts. These went into solution together with the potash and other soluble salts which were released as the fermentation processes decomposed the kelp. At the end of the fermentation period practically all of the kelp was in solution.



Courtesy Hercules Powder Co.

FIG. 35.—Overhead suction at wharf pumping kelp from barge to digestion tanks. Hercules Powder Company's San Diego, Cal. Plant.

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[20] *J. Ind. Eng. Chem.*, *10* (1918), 832-3, and *ibid.*, 858-9.

[21] Anon., *Met. Chem. Eng.*, *18* (1918), 576-80.

Courtesy Hercules Powder Co.

Potash from Kelp.

The above views show the plant of the Hercules Powder Co. at San Diego, Cal., where potash is recovered from kelp. The view at the top (Fig. 36) shows Digestion tanks for kelp. The center view (Fig. 37) shows at the left—Centrifugal building; right—Crystallizer building. The view at the bottom (Fig. 38) shows at the left front—Power house; right front—Machine shop; rear—Direct heat drier building.

After fermentation the resultant liquor was screened to remove undigested matter; then the solution was allowed to settle. After settling, the liquor was filtered through Oliver or Kelly filters. The filtrate contained sodium and potassium chlorides and iodides, and calcium acetate, propionate, butyrate, valerate, etc. Calcium acetate was present in larger proportions than any of the other organic salts.

The dilute solution was evaporated in quadruple effect Kestner evaporators. The principal trouble encountered in evaporation was the difficulty of keeping the evaporator tubes free from scale. In the process of concentrating the fermented liquor, a scum collected on the surface of the liquid. This scum consisted essentially of a mixture of calcium acetate, propionate, and valerate, all of which are less soluble in hot than in cold solution. This scum was called "taffy" by the workmen, on account of its plastic nature while hot. The taffy was made into solvent esters by mixing with ethyl alcohol and sulphuric acid and separating the resultant esters by fractionation.

The next substance to separate from the boiling solution was impure calcium acetate which contained some potassium chloride. This mixture was heated in retorts. Acetone and certain mixed ketones which had valuable solvent properties were distilled off and potassium chloride and calcium carbonate remained as a residue. The potassium chloride was leached from the insoluble calcium carbonate and recovered by crystalization.

After most of the calcium acetate had been crystallized out, the bulk of the potash came down as 95 to 98 per cent pure potassium chloride. The residue from the distillation consisted chiefly of potassium chloride and iodide. This was treated with a little chlorine; the precipitated iodine was dried and resublimed. Then the filtrate was evaporated to recover the potassium salts that it contained.

The unfermented leaves which were screened from the fermentation vats were used for the preparation of algin. These leaves were treated with a sodium carbonate solution which extracted the algin as the soluble sodium alginate which was afterwards precipitated and purified.

Fig. 39 is a products chart given by Higgins [20] in which the recovery of products from kelp is illustrated graphically.

In addition to the above products obtained by this process, the Hercules Powder Company has demonstrated the possibility of obtaining ammonia, valeric and caproic acids as by-products.

During the war over half the kelp harvested on the Pacific Coast was fermented in this plant. But immediately at the end of the World War the Hercules Powder Company suspended operations. Evidently this process was not profitable under normal conditions.

The Future of the Kelp Industry.

Since green kelp contains such a large amount of water, the cost of harvesting and drying it is very high. Results obtained from the operation of the kelp-potash plants during the war indicated that it was not possible to produce potash alone from kelp in successful competition with foreign potash. Only one privately owned plant operating during the war

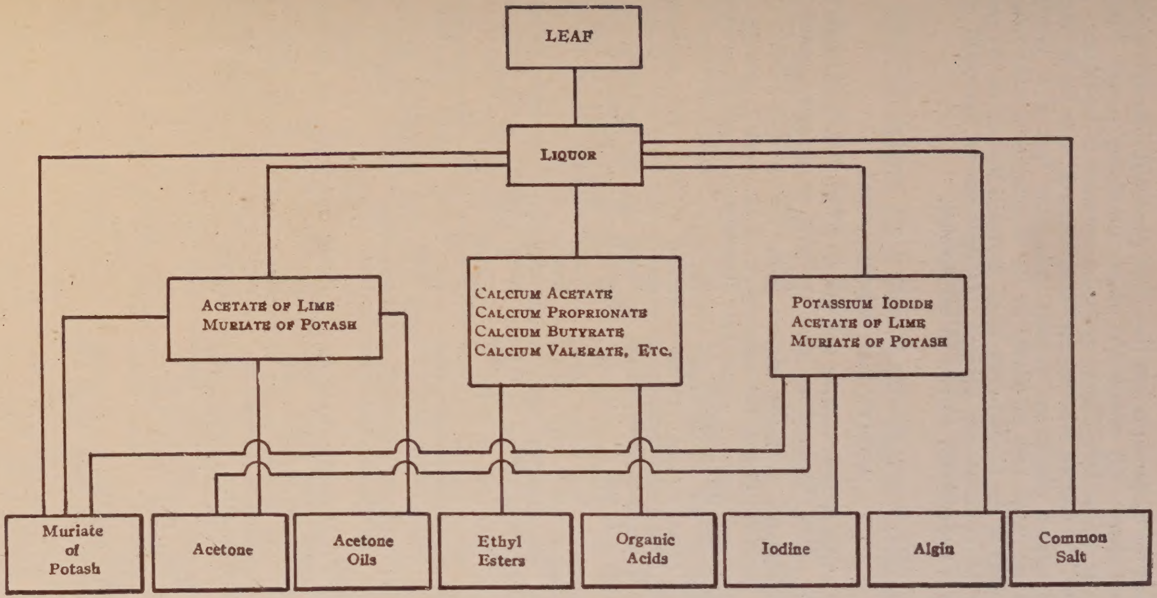

FIG. 39.—Flow sheet showing products obtained by the Hercules Powder Company's fermentation process.

was designed for by-products and that plant produced materials principally of war-time value. All commercial plants producing potash from kelp suspended operations immediately upon the cessation of hostilities.

Dr. J. W. Turrentine, who has had so much to do with the development of the destructive distillation process, maintains that it is possible to produce potash from kelp profitably by the distillation process even with potassium salts at the normal price level, provided that all the by-products which may be produced are utilized. If kelp can be harvested cheaply enough, he is undoubtedly correct in his opinion.

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Chapter 6.

Edible Algæ and the Agar-Agar Industry.

Importance of Algæ Used as Food.

Very little seaweed is eaten in America; because of this, few Americans consider algæ as important articles of diet. In many countries, especially in the Orient, algæ are consumed in large quantities. In Japan, seaweeds are of such commercial importance as vegetable foods that the natural supply is insufficient to satisfy the demand; therefore much attention has been given to their cultivation.

Over seventy varieties of seaweeds are used for food by the native Hawaiians; indeed fish and algæ are the chief foods eaten by the poorer classes of natives at certain seasons of the year. They also cultivate some of the more highly prized seaweeds.

Irish moss (*Chondrus crispus*) and agar-agar (chiefly from *Gelidium corneum*) are the chief seaweeds eaten in the United States. The center of the Irish moss industry in American is at Scituate, Massachusetts. Until recently no agar-agar was manufactured in the United States; now one factory is operating in California.

Irish moss is also the favorite edible seaweed in Europe. Green laver (*Ulva latissima*) and pink laver (*Porphyra laciniata*) are used in soups. Dulse (*Rhodymenia palmata*) is eaten by the Scotch people. Murlins (*Alaria esculenta*) are eaten by certain classes of the Irish people.

The Chinese and Swiss ate certain algæ to prevent goiter, long before they understood the cause of this disease. Various seaweeds have long been used for other medicinal purposes.

The Japanese market $2,000,000 to $3,000,000 worth of seaweed annually. No figures are available for the value of the Chinese seaweed product, but it is probably nearly as great.

Composition of the Edible Algæ.

Algæ as a class contain large amounts of carbohydrates, chiefly vegetable gums resembling pectin, ash, chiefly sodium and potassium chlorides, and small amounts of proteins and fats. Analyses of the giant kelps have been given in Chapter 5 (Tables 16, 17 and 18). The organic constituents of other algæ resemble those of the giant kelps in a general way.

When seaweeds are harvested, they contain from 80 to 90 per cent of water, which is comparable to the more succulent vegetables. Upon air-drying, their moisture content decreases to 25-10 per cent. Most edible seaweeds are marketed in the air-dry condition. The proximate analyses of the more important edible algæ are presented in Table 19, as given by Reed.[1]

TABLE 19

COMPOSITION OF EDIBLE ALGÆ

(Air-dry material)

	Water	Crude Protein	Fat (Ether extract)	Carbohydrates		Ash
				Sugar, starch, etc.[a]	Crude fiber	
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Irish moss (*Chondrus crispus*)[b]	18.8	9.4	....	55.4	2.2	14.2
Fat choy (*Nostoc commune flagelliforme*)[c]	10.58	20.93	1.19	55.73	4.07	7.50
Amanori or che choy (*Porphyra laciniata* or *vulgaris*)[c]	21.85	25.70	.17	37.68		14.60
Do.[d]	15.48	34.35	.65	38.83		10.69
Do.[d]	20.42	36.26	1.21	33.28		8.83
Do.[d]	16.40	35.63	.50	38.13		9.34
Do.[d]	14.58	32.44	.70	43.28		9.00
Do.[e]	13.98	33.75	1.30	41.22		9.75
Kombu or kelp (*Laminaria angustata*)[f]	22.82	5.49	1.52	46.93	4.55	18.69
Kombu or kelp (*Laminaria longissima*)[f]	25.94	6.72	1.73	31.90	6.42	27.29
Kombu or kelp (*Laminaria japonica*)[f]	22.97	4.00	1.59	47.49	5.83	17.16
Kombu or kelp (*Laminaria ochotensis*)[f]	23.99	6.65	.86	42.16	6.03	20.31
Kombu or kelp (*Laminaria religiosa*)[f]	22.75	4.72	.82	42.88	10.20	18.63
Kombu or kelp (*Laminaria fragilis*)[f]	23.10	4.03	.65	40.41	7.15	24.66
Kombu or kelp (*Arthrothamnus bifidus*)[f]	24.43	5.82	.74	45.58	6.44	16.99
Kombu or kelp (*Laminaria sp.*)[e]	23.08	7.11	.87	47.70		21.24
Kanten or seaweed gelatin[g]	22.80	11.71	....	62.05	....	3.44
Do.[h]	22.29	6.85	....	60.32	6.73	3.81
Awo-nori (*Enteromorpha compressa*)[i]	13.60	12.41	52.99		10.58	10.42
Awo-nori (*Enteromorpha linza*)[e]	13.53	19.35	1.73	46.18		19.21
Limu akiaki (*Ahnfeldtia concinna*)[j]	20.16	5.60	.07	54.96	2.66	16.55
Limu pahapaha (*Ulva fasciata* and *U. lactuca*)[f]	18.68	14.87	.04	50.65	.19	15.57

[1] *Ann. Rept. Hawaii Agr. Ex. Sta.*, 1906, 61-88.

TABLE 19—*Continued*

	Water	Crude Protein	Fat (Ether extract)	Carbohydrates		Ash
				Sugar, starch, etc.[a]	Crude fiber	
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Limu manauea (*Gracilaria coronopifolia*)[j]	12.87	7.91	.05	58.41	2.98	17.78
Arame (*Ecklonia bicyclis*)[k]	13.17	8.99	....	45.70	7.40	24.74
Do.[e]	18.75	9.58	.46	51.63	9.79	9.79
Hijiki (*Cystophyllum fusiforme*)[k]	16.40	8.42	....	41.92	17.06	16.20
Do.[e]	15.74	11.37	.49	54.84		17.56
Ulopteryx pinnatifida[e]	18.92	11.61	.31	37.81		31.35

[a] Computed by difference except in a few cases which were actually determined.
[b] United States Dispensatory.
[c] U. S. Dept. Agr., Office of Experiment Stations, Bull. 68, 47.
[d] Imperial Fisheries Bureau of Japan, quoted in *Bureau Fisheries Bull.*, *24* (1904), 160.
[e] Tahara, quoted in U. S. Dept. Agr., Office of Experiment Stations, Bull. 159, 40.
[f] K. Oshima, quoted in *Bureau Fisheries Bull.*, *24* (1904), 153.
[g] O. Kellner, quoted in *Bureau Fisheries Bull.*, *24* (1904), 141.
[h] Imperial Fisheries Bureau of Japan, quoted in *Bureau Fisheries Bull.*, *24* (1904), 141.
[i] O. Kellner, quoted in *Bureau Fisheries Bull.*, *24* (1904), 164.
[j] R. A. Duncan, food chemist for the Territory of Hawaii.
[k] E. Kinch, quoted in *Bureau Fisheries Bull.*, *24* (1904), 163.

Proteins of Seaweeds.

From Table 19 it is seen that the following seaweeds contain more than 20 per cent of protein (N content × 6.25) on a water-free basis: *Nostoc commune flagelliforme*, *Porphyra laciniata*, *Porphyra vulgaris*, and *Enteromorpha linza*. This is a relatively high protein content for whole plants. Most of the other algæ listed contain much less protein; however, if it were all digestible its presence would be of importance. Hoagland[2] has shown that over half of the nitrogen in *Macrocystis pyrifera* and *Nereocystis luetkeana* and a considerable proportion of the nitrogen contained in *Pelagophycus porra*, *Egregia manziesii*, *Laminaria andersonii*, and *Iridæa sp.* occurs in a non-protein form. Aside from this work, little has been done to show the nature of the nitrogen combinations in algæ.

The Ether Extract Content of Algæ.

All algæ contain small amounts of ether extract. Little work has been carried out to determine the proportion of fat in the ether extract. Sestini, Bomboletti, Benzoni, and Del Torre[3] state that water-free *Fucus vesiculosus* contains 0.91 per cent of fat while *Ulva latissima*, *Valonia ægogro-*

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[2] See Table 18.
[3] *Le Stazioni Spermentali Agragie Italiane*, *5* (1877), 207.

phila, Sphærococcus confervoides, Enteromorpha intestinalis, and *Zoostera mediterranea* contain less. *Solenia attenuata* contains 3.87 per cent and *Vaucheria pilus* 2.94 per cent of fat. Since the amount of ether extract is so small, its composition has not attracted attention.

Carbohydrates.

The carbohydrates in edible algæ consist chiefly of complex colloidal substances called vegetable gums. These make up the principal portion of the organic matter of algæ. Very little is known concerning the chemical nature of these substances; they include dextrans, galactans, mannans, pentosans and levulans, which when hydrolyzed yield dextrose, galactose, mannose, pentose, and levulose, respectively. Of the polysaccharides, the pentosans are the most abundant constituents of the algæ. Mannite is found in some of the sweet algæ, viz.: *Laminaria saccharina* and other laminaria, *Fucus vesiculosus, Alaria esculenta,* and *Rhodymenia palmata.*

TABLE 20

HYDROLYTIC PRODUCTS OF ALGAL CARBOHYDRATES

Species of Algæ	Anhydride of Hexoses			Anhydrides of Pentoses	
Porphyra	Galactose	Glucose	Fructose	Pentoses	
Porphyra tenera	Galactose	Glucose	Fructose	Pentoses	
Gelidium Raw	Galactose		Fructose	Pentoses	
Gelidium Bleached	d-Galactose		Fructose	Pentoses	
Gelidium cartilagineum	d-Galactose		Fructose	Pentoses	
Laminaria japonica		Glucose	Fructose	Pentoses	Methyl pentoses
Other *Laminaria*		Glucose	Fructose	Pentoses	
Cystophyllum			Fructose	Pentoses	Methyl pentoses
Cystophyllum fusiforme			Fructose	Pentoses	Methyl pentoses
Enteromorpha compressa		Glucose	Fructose	Pentoses	Rhamnose
Ecklonia bicyclis		Glucose		Pentoses	
Undaria pinnatifida	d-Galactose	Glucose	Fructose	Pentoses	Methyl pentoses

The algæ differ from the higher plants in another respect; their crude fiber content is very low because cellulose is either absent or present in very small amounts. Various observers have reported finding cellulose in seaweeds but its presence has not been definitely proven.

Ash Content.

Certain salts such as chlorides and iodides that are found in relatively large amounts in seaweeds have valuable physiological functions. Tables 6 and 7 in Chapter 4 gives nearly complete ash analyses of some common algæ. The composition of the ash of any given alga varies from day to day and from place to place; since it depends upon the age of the particular specimen and upon the temperature and movement of the sea water. Therefore the only reliable figures for ash analyses of given species are those which are the average of a large number of determinations on different specimens.

Digestibility of Algæ.

Carbohydrates.

Since rather far-reaching claims have been made as to the nutrient properties of some of the common edible algæ, the digestibility of the more important species has recently been the subject of comprehensive researches. Since about two-thirds of the dry matter of most algæ consists of complex carbohydrates, nearly all of the investigators have considered only the availability of these substances.

Algæ have long been used medicinally in certain countries for curing scorbutic and glandular affections. Agar-agar has been generally supposed to be very nutritious and has often been recommended as food for convalescents.

The results of the various researches on the digestibility of the carbohydrates of the algæ have not substantiated the assertions of those who claimed the highly nutritious character of edible seaweeds. Oshima[4] in summarizing the researches of the Japanese investigators concerning the digestibility of the nutrients of all common foodstuffs, placed the average digestibility of the carbohydrates in Japanese edible seaweeds at 67.7 per cent, which was the lowest coefficient of digestibility of the carbohydrates of any foods considered.

Saiki[5] studied the digestibility of agar, Irish moss, asakunori (various *Porphyra*), kombu (various *Laminaria*), and wakame (*Undaria pinnatifida*) by the human digestive enzymes and also by the human digestive tract. His conclusions follow:

> Experiments with a variety of alga and lichen preparations containing a large proportion of polysaccharide carbohydrates indicated that the latter were not readily transformed to sugar by carbohydrate digesting enzymes of animal origin and scarcely more readily by vegetable enzymes or bacteria. Corresponding with this, the digestibility and availability of such products in the alimentary tract were found to be very imperfect in both man and animals.

Swartz[6] has conducted comprehensive investigations in regard to the digestibility of the various classes of carbohydrates found in algæ. She concluded that in order of resistance to the action of bacteria the hemicellulose groups found in algæ stand as follows: galactans, pentosans, levulans, mannans. The galactan of *Chondrus crispus* was entirely unaffected by common microorganisms. The digestive enzymes were almost without action on these carbohydrates. Feeding experiments indicated that those hemicelluloses most readily attacked by bacteria disappeared most completely from the digestive tract. The average coefficients of digestibility of some carbohydrates from some common seaweeds are given in Table 21 by Swartz.

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[4] *U. S. Dept. Agr., Office of Ex. Sta., Bull. 159* (1905).
[5] *J. Biol. Chem., 2* (1906), 251-265.
[6] *Conn. Acad. Arts Sciences, 16* (1911), 249-382.

TABLE 21

Coefficients of Digestibility of Hemicelluloses

Hemicellulose		Subject of Experiment	
Class	Source	Dog	Man
		Per Cent	Per Cent
Pentosan	Dulse	73 (2 exp.)	100 (2 exp.)
Pentosan	Limu Eleele	35 (2 exp.)	9 (2 exp.)
Pentosan	Limu Pahapaha		34 (1 exp.)
Pentosan	Limu Lipoa	16 (2 exp.)	
Galactan	Irish Moss	33 (2 exp.)	6 (2 exp.)
Galactan	Limu Manauea	33 (2 exp.)	30 (3 exp.)
Galactan	Limu Huna	56 (2 exp.)	10 (1 exp.)
Galactan	Limu Akiaki		60 (1 exp.)[a]
Mannan	Salep Powder	85 (2 exp.)	97 (2 exp.)
	Salep Mannan	10 (1 exp.)	100 (2 exp.)

[a] Subject with chronic constipation.

Nitrogenous Constituents.

Little is known concerning the digestibility of the nitrogenous compounds contained in algæ. If all the nitrogen present were in the form of digestible proteins, it would make an important addition to their nutrient value. However, a considerable proportion of the nitrogen is probably in a form in which it cannot be utilized by the human digestive apparatus. Mention has previously been made of the work of Hoagland concerning the form in which the nitrogen occurs in certain Pacific Coast algæ (see Table 18). He found that a considerable proportion of the nitrogen occurs in a non-protein form. Hoagland's conclusions in regard to the digestibility of the proteins contained in the kelps follow:

> Although the percentage of acid amid nitrogen is apparently very small, it would still be necessary to prove that the remainder of the soluble nitrogen was present in the form of suitably proportioned amino acids, before a high nutritive value could be assigned to the material. Furthermore, the nitrogenous compounds would undoubtedly be rendered less available because of the admixture of large percentages of highly resistant polysaccharids.

Until further researches have been carried out to determine the digestibility of the nitrogenous compounds of algæ, no definite conclusions can be drawn.

In the face of the above evidence it must be concluded that algæ must be ranked as poor foods. Their anti-scorbutic properties may be due to their vitamin content, although this point has not been proved. Their value in the treatment of glandular affections is doubtless due to their high iodine content. They provide large amounts of inorganic salts such as potassium, sodium, magnesium, and calcium chlorides, which are needed by the human body for various physiological functions. Inasmuch as they add bulk to the food and absorb much water they are valuable foods for counteracting constipation.

Utilization of Algæ as Food in America.

The Irish Moss Industry.

The most important edible seaweed utilized in the United States is carrageen or Irish moss which is found along the Atlantic Coast from North Carolina to Maine, being especially abundant north of Cape Cod. Its chief use is in making blancmange and other puddings, but it is also used medicinally as a demulcent for coughs.

Irish moss (*Chondrus crispus*) is a common perennial algæ found on rocky sea shores. The densely tufted fronds are 2-10 inches high, narrow and sub-cylindrical at base, but soon becoming flat, repeatedly forked, very variable in breadth. The segments of the fronds are from 1-4 lines wide and are flat or curled. The color is various shades of purple or greenish. In shallow pools near high water mark it is generally yellow or pale green. Its substance is hard and horny when dry. Fig. 40 shows a single Irish moss plant.

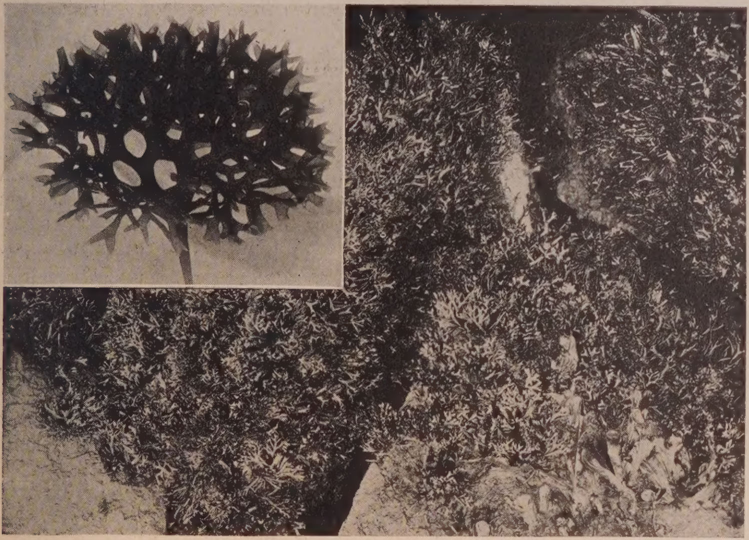

FIG. 40.—Irish moss growing on rocky shore near Scituate, Mass. Insert—A single plant of Irish moss.

Properties of Irish Moss.—Fresh Irish moss contains about 80 per cent of water. Field[7] gives the composition of the water-free substance as follows:

Gelatinous matter, 65 per cent.
Nitrogen, 2-3 per cent.
Lipoids, 0.7-1.0 per cent.
Ash, 10-15 per cent.

[7] *Bureau Fisheries, Ec. Cir. 51* (1921).

The ash contains calcium, sodium, potassium, magnesium, bromine, chlorine, iodine and sulphur.

The salts which it contains control the gelatinizing property of the gelose in the Irish moss; for if the salts are extracted by washing the moss in fresh water, a solution of the washed moss will not gel on cooling. On the other hand, if a solution of quickly dried unbleached moss, rinsed only in sea water, is prepared by boiling the moss in fresh water from three to five hours, it will form a stiff gel even though the proportion of moss to water is as low as 1 to 50.

The gelatinizing properties of Irish moss solutions are easily destroyed by the addition of small quantities of acids, alkalies and some salts. Calcium salts, according to Field,[7] increase the firmness of the Irish moss gel.

The Scituate, Massachusetts, Industry.

Prior to the year 1835 the small quantity of Irish moss used in this country was imported from Europe. The price at that time was from one to two dollars a pound. In that year Dr. J. V. C. Smith, at one time mayor of Boston, made it known that this moss abounded on the Massachusetts shores. From that time to the present, Irish moss has been cured at Scituate, Massachusetts. Because of the abundance of the moss the price rapidly dropped, and in 1880 it sold for about three cents a pound; in that year the yield was about 450,000 pounds. In 1898 the output was 770,000 pounds valued at $24,825; and in 1902, 740,000 pounds valued at $33,300 were sold. By 1919, the production had decreased to 212,200 pounds valued at $15,687.

The center of the Irish moss industry is still at Scituate, Massachusetts, where about thirty men are employed in the collecting of the moss. Other localities where the moss is harvested are Cape Porpoise, Portsmouth, York, and Rye, N. H.; Cape Sable, Rockport, Gloucester, Marblehead, Nahant, Cohasset, Plymouth, White Horse Beach and Cuttyhunk Island, Mass.; Block Island and Montauk, N. Y.

Dr. Hugh M. Smith[8] has described the manner in which Irish moss is gathered and cured on the New England coast as follows:

> A small part of the crop is gathered by hand, but most of it is torn from the rocks by means of rakes used from boats. The rakes are made especially for the purpose, and have a 15-foot handle and a head 12 to 15 inches wide, with 24 to 28 teeth 6 inches long and an eighth of an inch apart.
>
> The gathering season extends from May to September. If the rocks are not scraped too clean in the early part of the season, it is said to be possible to get two crops in some of the warm, sheltered coves, where the alga grows much faster than in the more exposed places.
>
> The output in recent years has varied considerably, owing chiefly to the inclination or disinclination to engage in the business. Some years a large number of people seem moved by a desire to gather the weed, while other seasons only a few go into the business. Occasionally heavy storms do damage by tearing the plant from the rocks and scattering it along miles of beach. There is said to be a scarcity at times, owing, it is supposed, to too active gathering the previous season, the rocks being almost completely denuded.
>
> In the preparation and curing of Irish moss fair weather and much sunshine are prime requisites. When first brought ashore, the plants are washed in salt water

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[8] *Bureau Fisheries Bull., 24* (1904), 169-181.

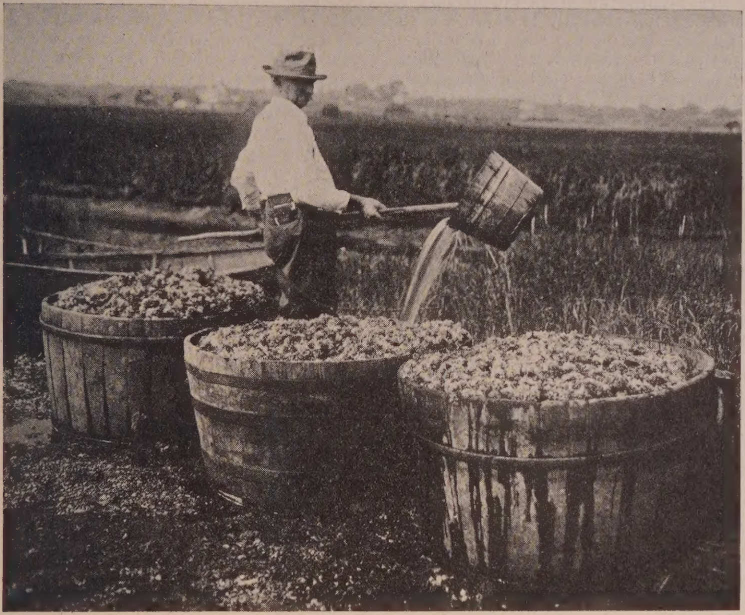

FIG. 41.—Washing Irish moss preparatory to bleaching.

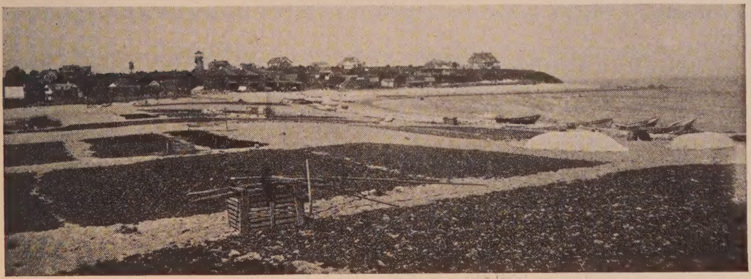

FIG. 42.—Irish moss bleaching and drying on the beach near Scituate, Mass.

and then spread upon the sandy beach to dry and bleach. After twenty-four hours in good weather they are raked up and again washed and again spread on the beach to dry. Three washings are usually sufficient for complete cleansing, curing, and bleaching, but as many as seven are sometimes given. After the final washing the plants are left in the sun, the entire process requiring about two weeks of good weather and warm sunshine. The plants gradually fade, and by the time the curing is finished they are white or straw colored. Two more weeks are then required to sort and prepare the product for shipping.

Great care has to be exercised in the curing to prevent the rain from spoiling the crop, and when a storm is impending the moss is hastily raked in piles and covered with canvas. Should it chance to get wet in the last week of its curing, it is practically ruined.

American Uses for Irish Moss.—Irish moss is sold chiefly for use in making blancmange, and other puddings and jellies. It is also used for clarifying beers and in the sizing of fabrics.

Dulse.

Dulse (*Rhodymenia palmata*) is found abundantly on the rocky shores of the Atlantic Ocean from North Carolina to Maine. It is particularly abundant in New England where it is dried in the sun and eaten as a relish. In Philadelphia it is called sea-kale and eaten as a vegetable. It is sold in some stores in New England towns along the coast.

"Seatron" from *Nereocystis Luetkeana.*

Mr. H. M. Colvin and Dr. T. C. Frye prepared an article of food which they called "seatron" from the kelp *Nereocystis luetkeana* by leaching out the salts and preserving in a syrup. This product may be flavored as desired, but is usually sold as an imitation of candied citron.

Seaweeds Eaten in Europe.

Irish moss (*Chondrus crispus*) is the most widely used alga in Europe. It is obtained chiefly from Clare and the western coast of Ireland. As in America it is sold for making blancmange, puddings and sea moss farina.

Dulse (*Rhodymenia palmata*) commonly called dillish, dulling, and water leaf has an odor of violets and a slightly acrid taste. At one time the dried plant was commonly chewed by the Scotch and Irish, but it has been superseded by tobacco. It is now used as a condiment; it is a favorable ingredient in ragouts, to which it imparts a red color and thick consistence.

Porphyra laciniata is called laver in England, sloke in Ireland, and slack in Scotland. It is served in various ways: sometimes it is boiled for hours, and when reduced to a pulp, eaten with lemon juice; at other times it is boiled and seasoned with spices and butter.

Fucus vesiculosus, bladder wrack, lady wrack or black tang, is sometimes used medicinally in the treatment of goiter, as is also *Laminaria digitata.* These algæ are also considered antiscorbutics.

Ulva latissima, oyster green or green laver, is eaten in the same manner as porphyra, but is considered inferior to it.

Laurencia pinnatifida, or pepper dulse, has pungent properties and is used as a condiment in Scotland.

Alaria esculenta, or murlins, are gathered on the coast in Scotland, Ireland and Iceland, cooked, and eaten.

Other algæ commonly eaten in Great Britain include the following: *Iridæa edulis* (called dulse), *Chondrus mamillosus,* agar-agar (*Gelideum corneum*), and *Laminaria digitata* (commonly called tangle, sea girdles, red ware and seawand).

The Oriental Edible Algæ Industry.

The Orientals utilize seaweeds for food to a far greater extent than the Occidentals. The edible seaweed industries are among the most valuable of the aquatic industries of the Japanese Empire. Much Japanese seaweed is exported to China, Hawaii and the United States. Owing to the dense Japanese population and the mountainous character of the islands the agricultural products are limited and the inhabitants are forced to look elsewhere for their food. Since the Japanese islands are so numerous the total extent of the coast-line is very great, being about 18,000 miles, and the amount of seaweeds on the coast is very large. The number of poor among the Chinese is very great and inasmuch as most seaweeds constitute a very cheap food, they are much eaten in China. The Chinese congregated in American cities import considerable quantities of dried and prepared seaweeds from China and Japan.

The two most important species of algæ which are cultivated in Japan are "amanori" or red laver (*Porphyra tenera*) and "funori" (*Gloiopeltis furcata*). The method of cultivation of the porphyra has been described by Smith [9] in his paper *Seaweed Industries of Japan.*

> In October and November (in Tokyo Bay) the grounds are prepared for the seaweed crop by sinking into the muddy bottom, in water up to 10 to 15 feet deep at high tide, numerous bundles of bamboo or brush. These bundles are prepared on shore and taken to the grounds in boats at low tide, one or two men constituting a boat's crew. The bundles of brush are planted in regular lines, deep holes being made for them by means of an elongated conical wooden frame with two long, upright handles, which is forced into the mud by the weight of the fisherman.
>
> The object of these lines of brush is to intercept and afford a lodgment for the floating spores of *Porphyra.* The spores become attached to the twigs and grow rapidly, so that by the following January the plants have attained full size and are harvested from January to March, being cut from the brush as they grow. They die about the time of the vernal equinox, and the active business is at a standstill until the ensuing fall. During summer, however, the old brush is removed from the grounds, and fresh material is collected and prepared.
>
> The best grounds for growing *Porphyra* are in great demand, and the fishermen are often in conflict over them. The local governments lease the planting privileges. In Tokyo, where five classes of licenses are issued, depending on the yield of the grounds, the license tax is from 0.20 to 0.70 yen.

A very large number of species of algæ are eaten by the Japanese. Yendo [10] has described twenty-six species of edible Japanese algæ.

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[9] *Bureau Fisheries Bull., 24* (1904), 133-165.

[10] *Postelsia, Yearbook Minn. Seaside Station,* 1901, 3-18.

Preparation and Use of Amanori or Red Laver.

Of the various edible species utilized by the Japanese amanori (variously called *Porphyra laciniata, P. vulgaris, and P. tenera*), kombu (kelp), and tengusa (species of *Gelidium* chiefly *G. corneum*) are considered of the most importance.

About a thousand acres of amanori are cultivated which yield a crop valued from $150 to $300 an acre. In Tokyo Bay alone more than three thousand persons are employed in its cultivation.

While small quantities of amanori are eaten fresh, the bulk of the crop is preserved by drying in the sun. After it is gathered from the twigs, on which it is grown, it is washed in fresh water and sorted. Then the seaweeds are chopped fine with hand knives. The chopped weed is spread on small mats of fine bamboo splints and made into thin sheets. The mats are placed on inclined frames in the open air. When completely dried, the sheets of amanori are stripped from the mats, and, after pressing flat, they are arranged for market in bundles of ten. The sheets have a glossy surface, are thin and flexible like writing paper, and are of a mottled brownish purple color. Their dimensions are approximately 10 by 14 inches.

Amanori is usually baked over a fire until its color changes to green. This treatment makes it crisp. It is either eaten with soups or broths or made into "sushi." Sushi corresponds to the sandwich, and is prepared by placing boiled rice upon a sheet of amanori, and then placing strips of meat or fish on the rice. The whole is rolled up and cut into transverse slices.

The analyses of various grades of amanori are presented in Table 22.

TABLE 22

ANALYSES[a] OF VARIOUS GRADES OF ASAKUANORI OR AMANORI

Sample	1	2	3
Price (sen) of 100 gm. of dried sample	74.8	52.8	52.7
In 100 gm. of original sample.			
Dry matter	96.44	93.62	93.94
Total N	6.20	5.26	4.60
Protein N	5.05	4.23	3.70
Non-protein N	1.15	1.03	0.90
Organic base N	0.04	0.02	0.03
Monoamino-acid N	0.18	0.22	0.14
Other N	0.93	0.79	0.73
Carbohydrate (as starch)	21.96	19.94	22.23
NaCl (calculated from total chlorine)	2.60	2.53	5.00
In 100 gm. of dried sample.			
Total N	6.43	5.62	4.90
Protein N	5.24	4.52	3.94

[a] From Okuda, Y., and Nakayama, S., *J. Coll. Agr., Imp. Univ. Tokyo, 5* (1916), 339-40.

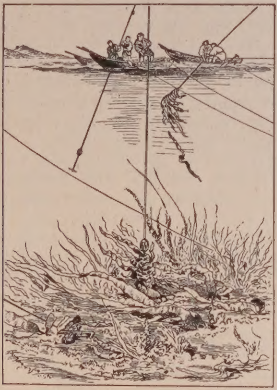
Kombu.

The Japanese prepare certain kinds of food called kombu from various seaweeds belonging to the kelp family (*Laminariaceæ*) which are chiefly obtained from Hokkaido, the most northern of the main islands of the

Japanese archipelago. The species most used in kombu manufacture are the following: *Laminaria japonica, L. religiosa, L. angustata, L. longissima, L. ochotensis, L. vezœnsis, L. fragilis, L. diabolica, L. gyrata, Arthrothamnus bifidus* and *kurilensis,* and *Alaria fistulosa.*

The principal centers of the kombu industry are Osaka, Tokyo and Hakodate. In Osaka there are about 45 factories, each employing from 10 to 30 persons. The kelp is gathered in the summer by fishermen who go to the kelp grounds in open boats. The men tear or twist the kelp plants from the bottom by means of hooks, some of which are attached to long wooden handles and others are weighted and dragged on the bottom by means of ropes.

The kelp which is gathered in this manner is spread on the beaches to dry. The stems of the dried kelp are cut off and the fronds are sorted as to size and quality. The trimmed, sorted kelp is then packed into long flat bundles and shipped to kombu manufacturers.



Courtesy Bureau of Fisheries.

FIG. 43.—Hooking kombu in Japan.

Kombu is prepared for use in a dozen or more forms. The most important form manufactured is shredded green dyed kombu. This is prepared by dyeing the dried kelp a green color in a large kettle containing a boiling solution of malachite green. The dyed kelp is drained and partially dried. After partially drying, the fronds are flattened out and arranged in wooden frames in piles about 18 inches high, 5 or 6 inches wide and the full length of the fronds. Each pile is then tightly compressed and held by four transverse cords, and cut into four equal lengths. The cut fronds are arranged by hand in a rectangular frame 4 to 5 feet square, and the same length as the sections of kelp. When the frame is completely filled with the evenly arranged pieces, the whole mass is compressed by means of ropes, wedges, and levers. One of the sides of the frame is then removed and the kelp shredded by means of a hand plane. The shredded kelp is spread on board platforms or on mats and dried in the open air. When the surface of the shreds has become dry it is packed for shipment. The product resembles in color, shape and feel the Spanish moss which festoons the trees in the southern part of the United States. Bulletin No. 24 of the United States Bureau of Fisheries[9] contains descriptions of other forms of kombu preparations which are given below:

(a) The entire frond is dipped in vinegar until thoroughly soaked, then drained and dried in the open air. The vinegar used is of Japanese make and of the best quality, and is diluted with a very little water. The vinegar softens the frond and leaves it pliable; it also imparts a flavor and doubtless has a slight preserving effect. Its chief supposed or intended action, however, is to permit the special treatment which will be described. Fresh water would have the same softening effect, but would spoil the seaweed for the purpose in view.

(b) With a raw-edged knife shaped like a mince-meat chopper, the Japanese artisan, holding the broad frond taut with hand and foot, scrapes the epidermis from both sides. This outer skin, which comes away in shreds, is the cheapest grade of kombu, containing more or less grit or dirt. A second scraping brings away all of the remaining green covering, and leaves only the thick white core of the frond. This product is called *kuro-tororo* (black pulpy) kombu.

(c) The scraping is continued with a raw-edged knife, and a fine, white, stringy mass results, which is known as *shiro-tororo* (white pulpy) kombu.

(d) A sharp-edged knife may be used after the green coats are removed, and the scrapings then take the form of exceedingly thin and delicate filmy sheets of irregular sizes; this preparation is named *oboro* (filmy) kombu.

(e) The remaining central band of the frond, now very thin and no longer workable in this way, is pressed into bundles with similar pieces, divided into equal lengths, and with a plane cut edgewise into shreds after the manner of the green-dyed kombu. The shavings resemble coarse hair, and the preparation has received a name (*shirago kombu*) which means white-hair kombu.

(f) Fronds from which the outer green skin has been more or less completely scraped are often cut into small pieces of various shape—strips, squares, oblongs, circles, fans, etc.—which are then dried over a fire and made crisp; the long strips are frequently tied into peculiar loose knots. These pieces are placed on the market in this form, when they are known as *hoiro* (dried-on-the-fire) kombu; or they are coated with a hard white or pink icing and called *kwashi* (sweet-cake) kombu.

(g) The dried pieces just mentioned are sometimes pulverized and put through a fine wire sieve like a flour sieve, yielding a slightly greenish or grayish flour. A white and still finer powder is made from the deeper layers of the frond. The powdered preparations are named *saimatsu* (finely powdered) kombu. Such powders are sometimes compressed into small cakes of various shapes and coated with sugar.

(h) A form of kombu known as *cha* (tea) kombu is prepared by taking fronds which have been subjected to the first scraping process, reducing them to shreds in the usual way by planing and, after drying, cutting the shreds into half-inch lengths comparable to the rolled leaves of green tea.

Kombu is one of the standard foods of Japan. The green-dyed and shredded kombu is cooked with meats and soups and is also served as a vegetable. The powders are used in sauces, in soups, and on rice, like curry powder. The tea kombu and the green and white powdered kombu are used as tea, boiling water being poured on a small amount of the kombu in the preparation of the drink.

Miscellaneous Edible Japanese Algæ.

Amanori and kombu are the two most important Japanese edible algæ. Other seaweeds commonly eaten in Japan are listed below.[11]

[11] *Ulva lactuca* (Aosa); *Enteromorpha linza* and *E. intestinalis* (Awonori); *Codium mucronatum* and *lindenbergii* (Muru); *Phyllitis fascia* (Haba-nori); *Chordaria abietina* (Matsumo); *Mesogloia decipiens* (Mozuku); *Undaria pinnatifida*

Information as to the methods of preparation and serving these algæ can be found in an article by Yendo in Postelsia.[10]

The Edible Seaweeds of Hawaii.

The Hawaiians, like the Japanese, are fond of many seaweeds. They gather and eat many tons daily and also import large quantities from the Orient. Edible algæ are called limu by the natives. Before the coming of white men to the Hawaiian Islands, the diet of the natives was largely poi, a thick paste made from the root of the taro plant, fish and limu; and to-day seaweeds constitute the chief portion of the vegetable diet of the poorer Hawaiians.

About forty distinct species of algæ are in general use as food in Hawaii, and about thirty other species are occasionally eaten. The most popular varieties of limu are limu eleele (*Enteromorpha flexuosa* and *E. hopkirkii*), limu kohu (*Asparagopsis sandfordiama*) and limu lipoa (*Haliseria pardalis* and *H. plagiogramma*). Other important edible seaweeds are limu manauea (*Gracilaria coronopifolia*), limu huna (*Hypnea sp.*) and limu pakælewaa (*Grateloupia filicina*).

The Hawaiians preserve limu by simply salting and tying closely in several layers of ti leaves and placing in a cool place. The leaves keep the seaweed from drying and also help to keep it crisp. Salted pounded limu is kept in calabashes or glass jars; occasionally it is preserved in weak brine.

The greater proportion of the limu gathered is not preserved but is immediately washed and prepared for eating. After cleaning, the seaweed is salted and broken, pounded, or chopped into small pieces, and usually eaten without cooking as a relish with poi, meat or fish. Lima huna is often boiled with squid and produces a jelly of which the Hawaiians are very fond.

Algæ Eaten in Other Parts of the World.

Comparatively little has been written about the edible marine algæ industry of other parts of the world. Much seaweed is gathered and eaten in the East Indies.

Laminaria potatorum, or large sea tangle, is said to be an important article of diet of the natives of Australia, New South Wales and New Zealand. A brown algæ, *Durvillæ utilis,* is eaten in considerable quantities by the natives of Chile.

The Agar-Agar Industry.

The Nature and Importance of Agar-Agar.

Agar or agar-agar is the commercial name applied to the dried, partially bleached, gelatinous extract of certain species of red algæ

(Wakame); *Cystophyllum fusiforme* (Kijiki); *Nemalion lubricum* (Umi-zomen); *Chrondrus elatus; Gigartina teedii* (Catanori); *Gymnogongrus flabelliformis* (Okilsunori); *Sarcodia sp.* (Tasoka); *Gracilaria confervoides* (Ogo-nori); *Digenia simplex* (Makuri); *Campylæphora hypnoides* (Ego); *Gloiopeltis calliformis* (Funori) (chiefly used as an adhesive and as a size); *Grateloupia affinis* (comenori); and *Grateloupia filicina* (Mukade-nori).

(*Florideæ*). Agar has been known in the Orient for several centuries under the various names of agar-agar,agar agar gum, kanten, Oriental or Japanese isinglass, hai thao, agal agal, Bengal isinglass, Bengal isinglass gum, Ceylon moss, and Chinese moss. At first the algæ were simply dried in the sun; later a jelly was prepared by the boiling of the seaweed. It is probable that the present manner of preparation was discovered accidentally by the chance freezing and thawing of a sample of jelly.

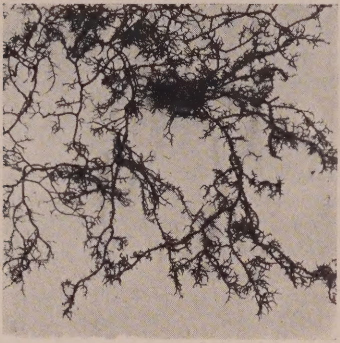


Photo by J. M. Wistgate.

FIG. 44.—Lima huna.

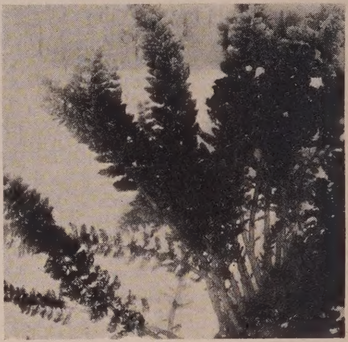


Photo by J. M. Wistgate.

FIG. 45.—Limu kohu.

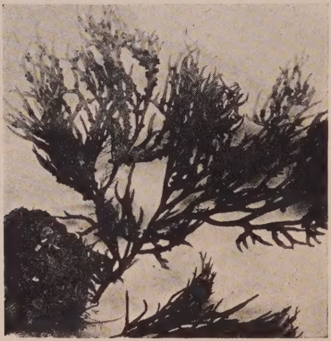


Photo by J. M. Wistgate.

FIG. 46.—Limu manauea.

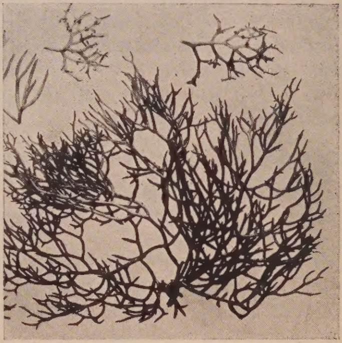


Photo by J. M. Wistgate.

FIG. 47.—*Gracilaria coronopifolia,* also called limu manauea.

HAWAIIAN SEAWEEDS.

Most of the agar of commerce comes from Japan, China, Malaysia, Ceylon and neighboring coasts, although recently an industry has been started in the United States on the California coast. The Ceylon and Chinese agars are derived mainly from *Gracilaria confervoides*. In Java and Malaysia the principal alga used in its manufacture is *Eucheuma spinosum.* The Japanese agar which is obtained chiefly from *Gelidium corneum, Camphylaphora hypnœoides* and certain species of *Gracilaria* is usually the finest obtainable on the market.

Properties of Agar-Agar

Agar comes on the market as porous, translucent sheets 8 to 12 inches long and 1 to 1.5 inches wide, as rectangular blocks about 8 inches long and 1 inch square, as shred agar in bundles of ribbons, and in the ground form. It is usually purchased as shred or ground agar for bacteriological work, and should be nearly colorless. Commercial agar varies widely in color from colorless to yellow, pink or black.

Agar swells rapidly when placed in cold or lukewarm water and eventually becomes a very stiff gel, retaining its original form. It must be boiled in water for some time to dissolve it. A one-half per cent solution of agar will form a stiff gel when cooled to room temperature. The melting point of the gel depends to some extent upon the concentration of the solution. Other factors affecting the melting point of the gel are the treatment of the agar during its manufacture, the source of the agar and the presence of impurities in the agar. Certain salts lower the melting point of the gel to a remarkable extent; other salts raise the gel point.

Agar gels are excellent for the study of reversible colloids. Much of the work done on the nature of gelatin gels has been checked with similar work on agar gels. Lewites [12, 13] compared the action of many acids, bases and salts upon gelatin and agar gels.

A carbohydrate, pectin-like substance called d-galactan or gelose is the chief constituent of agar, and gives to it its characteristic properties. Three per cent of hydrochloric acid causes agar to lose its power of forming a gel with water. When this acid solution is neutralized and evaporated to dryness a sweet syrupy solution is produced. Other mineral acids produce a rapid hydrolysis of agar.

The average, proximate analysis of fifteen samples of commercial agar was reported by Fellers: [14]

Moisture	16.57%
Protein (N × 6.25)	2.34
Nitrogen-free extract (chiefly gelose)	76.15
Ether extract	0.30
Crude fiber	0.80
Ash	3.85
Silica (SiO_2)	0.68

Table 23 gives the results of more detailed analyses of purified agars made by Fellers. The purified agar is lower in nitrogen than the commercial product; for when agar is washed with water, dissolved and then precipitated with alcohol it loses about sixty per cent of its nitrogen.

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[12] *J. Russ. Phys. Chem., 34,* 110, and *35,* 253.

[13] *Zeits. Chem. Ind. Kolloide, 2* (1907-8), 161-170, 208-215, 237-241.

[14] *J. Ind. Eng. Chem., 8* (1916), 1128-1133.

TABLE 23

ANALYSIS OF PURIFIED AGARS

Sample No.	1	2	16[a]	Average
CaO	1.02%	0.82%	....	0.92%
MgO	0.595	0.540	....	0.568
Na_2O	0.235	0.264	....	0.25
K_2O	0.062	0.072	....	0.067
$Fe_2O_3+Al_2O_3$	0.57	0.52	....	0.55
SiO_2	1.11	0.55	0.29	0.83
SO_3	2.65	0.264	1.11[b]	2.645
P_2O_5	0.056	0.048	....	0.052
As_2O_3	—	—	....	—
Cl	0.26	0.17	+	0.22
I	+	+	....	+
Pentosans	2.996	3.236	....	3.12
Galactan	24.34	21.40	....	22.87
Solution in H_2O at 20° C.	19.1	18.9	3.08	19.00
Solution in H_2O at 100° C.	96.5	95.9	98.77	96.20
Protein in alcohol precipitate	0.94	1.30	....	1.12
Cc. excess N HCl per gram agar	0.034	0.024	....	0.029

[a] Not included in the average.
[b] SO_3 in the ash.
+ Detected but not estimated.
— Negative results in the tests.

Purification of Agar.

Recently some attention has been given to processes of purification of agar. Merck[15] has patented a process which consists essentially in dissolving impure agar in hot water, filtering and freezing. The agar is then warmed, whereupon water containing some of the impurities separates and is allowed to drain off. The gel is washed with cold water until the washings contain no solid matter in solution. This treatment removes the impurities soluble in cold water. Fellers[14] has suggested washing shredded agar in dilute acetic acid solution and then with water. The washed agar is dissolved in hot water and precipitated from the hot solution by means of a large volume of alcohol or acetone. This procedure removes much of the nitrogenous matter contained in the agar, and the gels prepared from this purified substance are transparent.

Species of Algæ Used.

Most of the algæ used in the preparation of agar belong to the red algæ or *Florideæ*. The weeds most commonly used are *Gelidium corneum, Gelidium cartilagineum, Gracilaria confervoides* (also called *Fucus amalyaceus*), *Gracilaria lichenoides, Gracilaria tenax, Eucheuma spinosum, Acanthopeltis Japonica,* and *Camphylæphora hyphoides.* The most important of these are those of the genus *Gelidium* of which *G. corneum* is the principal species used. In Australia the most important algæ used for making agar-agar is *Eucheuma spinosum. Gracilaria lichenoides* is commonly used in Ceylon.

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[15] German Pat. 272,145 (1913).

Gelose Content of Algæ.

Gracilaria lichenoides contains according to Simmonds[16] about 70 per cent of a "vegetable jelly." Field[7] gives the gelose content of some other algæ when sun dried as follows: *Gelidium cartilagineum* 40-45 per cent; *Gelidium amansii* 28.9 per cent; *Gelidium australe* 32-37 per cent. However, he also notes that the gelose contained in *Gelidium australe* was not as good as that prepared from *G. corneum.*

Matsui[17] has analyzed the three chief types of seaweeds used in the manufacture of Japanese agar; his results are summarized in Table 24.

TABLE 24

ANALYSES OF PRINCIPAL JAPANESE SEAWEEDS USED IN THE MANUFACTURE OF AGAR

	Per Cent of Dried Material		
	Tengusa (various species of *Gelidium*)	Yegonori (*Camphyla-phora*) *hyphæbides*	Ogonori (various species of *Gracilaria*)
Ash	4.23	3.04	3.54
Lime	0.28	0.48	0.39
Magnesia	0.52	0.94	0.84
Alumina	....	0.45	0.55
Nitrogen	2.01	2.19	0.69
Crude Protein	12.56	13.67	4.29
Fiber	17.89	12.25	4.32
Galactan	23.70	24.88	22.14
Pentosan	2.30	5.19	1.21
Methyl Pentosan	0.93	2.13	0.97
Reducing sugars after hydrolysis with dilute acid	23.20	48.38	45.20

Commercial Applications of Agar.

Agar-agar has long been used for food in the Orient and is one of the favorite seaweed foods of the Japanese and Chinese; it is eaten in the form of jellies and as a thickener of soups, sauces and gravies. It is also eaten in Europe and the United States chiefly in food preparations such as ice cream, jellies, candies, pastries and in many desserts. It is also used in the canning of fish to prevent the soft canned fish from being shaken to pieces during transportation; agar fills this purpose very well since a very dilute solution of it forms a firm gel upon cooling. For this purpose it is far superior to gelatin since the gel strength of gelatin is rapidly destroyed at the temperature at which canned fish is sterilized. Some agar finds use in the clarification of liquors. A limited amount is used as a sizing material. Its chief uses in Europe and America are for the preparation of bacteriological media for scientific use and as a laxative. Its action as a laxative is dependent upon the fact that it has the property of absorbing and holding water, becoming at the same time a lubricant and a mild stimulant. Recently agar has been used with considerable success as a dressing for certain types of wounds.

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[16] *J. Soc. Arts, 5* (1857), 363-365.

[17] *J. Coll. Agr. Imp. Univ. Tokyo, 5* (1916), 413-7.

The American Agar Industry.

The agar industry is one of the few novel American industries that have been introduced since the World War. In 1920, a factory having a capacity of approximately one ton a day was built at Tropico, California.

The varieties of algæ, which may be used for the manufacture of agar, that are found in sufficient quantities on the California coast to be of commercial importance are the following: *Gelidium corneum, G. cartilagineum, Gracilaria confervoides, Eucheuma spinosum* and various species of *Tenax* and *Gigarteneæ.*

The red seaweed is collected from water up to eight fathoms in depth by men in boats. When the weed is brought ashore it is partially dried and transported to the factory.

The first step in the manufacturing process is the bleaching treatment. The seaweed is spread out in the sun and washed with a whirling spray of water. The colorless seaweed is placed in a large tank where it is steamed until it is in solution. When this is accomplished the solution is run into a settling tank where it is permitted to stand until all the suspended matter contained in the solution has settled. The clarified agar solution is then siphoned off and run into frames where it is allowed to gel. The blocks of jelly are cut with wire into strips about 12 inches long and one-fourth inch square. These are placed on canvas frames and carried into the freezing room, where the agar jelly is frozen at a temperature of about —10° C. When frozen they are taken out of the freezing room into the sun which melts the frozen strips. As the jelly melts the water runs out leaving a very porous strip which quickly dries in the sun. The dried strips are tied into one pound bundles and are ready for market.

The Japanese Kanten Industry.

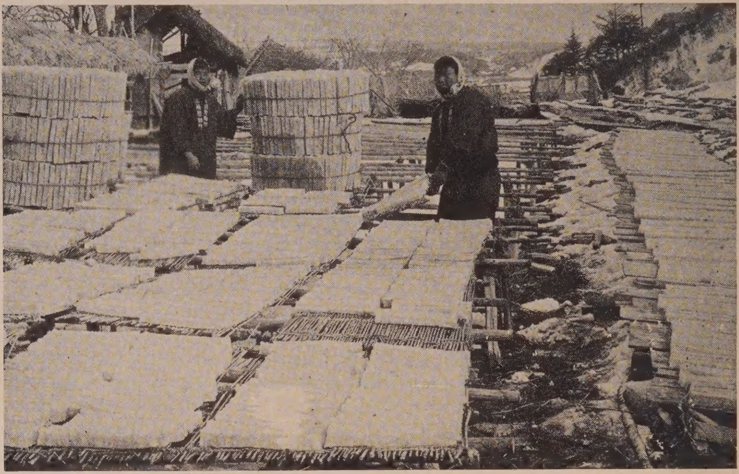
Kanten, or agar, has been manufactured in Japan since about the year 1760. The best grade of kanten is prepared from "tengusa" (*Gelidium corneum*) and this alga is the chief source of the Japanese agar. "Yegonori" (*Camphylaphora hypnœoides*) and "ogonori" (various species of *Gracilaria*) are also used in the manufacture of kanten. The analyses of these Japanese algæ were given in Table 24.

The early history of the kanten industry is discussed in Smith's[9] "Seaweed Industries of Japan." The value of the kanten exported from Japan increased from $33,131.00 in 1869 to $554,272.00 in 1902. And in 1918 there were 381 factories producing kanten. These factories employed 4,258 persons and manufactured 3,789,225 pounds of kanten valued at about $1,750,000.00. Osaka is the most important production center, manufacturing about 42 per cent of the above total, whereas Nagano produced about 23 per cent, Kyoto 18 per cent, and Hyogo about 14 per cent. However, the year 1918 was a year of overproduction of kanten and was followed by 1919 in which there was a considerable decrease both in the amount and value of the kanten produced.

The Japanese Method of Manufacture.

The red algæ used in the manufacture of kanten grow on rocks in relatively shallow water and are gathered from small boats either by means of rakes with long handles or by diving. The gathering season extends from May to October; July and August are the best months. The seaweed is spread upon the beach to dry; some bleaching takes place during the drying process. It is then sold to manufacturers. Until recently all Japanese agar was manufactured in the winter time, and for that reason the summer crop had to be stored until the cold months. Recently, however, refrigeration machines have been introduced, so that those manufacturers employing them may operate their factories the entire year if desired. In order to have a long cold season most of the kanten factories are located back away from the ocean in the hills and mountains where cold nights come early in the autumn.

The first operation in the Japanese process of making kanten consists in the cleaning of the "tengusa" or other seaweed. This is accomplished by beating and pounding the weed until most of the shells, sand and other foreign matter is removed, and then washing the algæ in cold fresh water. The wet tengusa is spread out to dry on flakes in the sun. The seaweed is then alternately wet by sprinkling with water and dried in the sun until it is bleached nearly colorless. As the drying and bleaching progresses the algæ become matted together and form loose-meshed sheets. The bleached raw material is boiled with about fifty times its weight of water in an iron kettle for five or six hours until practically all of the seaweed has gone into solution. In some plants direct steam is used to effect the boiling; in this case wooden vats are used in place of the iron kettles. After about five hours' boiling a small amount of vinegar or sulphuric acid is often added to hasten the solution of the seaweed. If vinegar is added about one part of vinegar is added for each hundred parts of dried tengusa in the kettle; when sulphuric acid is used only one part of this acid is added for each 1,000 parts of seaweed. The boiling is usually continued about a half hour after the addition of the acid or until all of the gelose is extracted from the seaweed. The digested portion is separated while hot from the fibrous residue by straining through coarse hemp or cotton cloths stretched over a frame, beneath which is placed a large vat, into which the solution filters. The preliminary straining is followed by a more complete separation of the insoluble matter by squeezing the solution through a linen bag of finer mesh in a press. The dregs which remain behind in the bags are collected and boiled again for about four hours and strained in the same way. The solution is run from the press into a large vat where it is allowed to settle for a short time, and it is then dipped out of the vat and poured into wooden trays about 2 feet long, 1 foot wide and 3 inches deep. When cold a firm jelly is produced which the Japanese call "tokoroten." The jelly is then cut into the desired shape. If shredded agar or slender kanten is desired, the cakes of jelly are cut by means of sharp knives into blocks 1 foot long and 2 inches square. These blocks are then forced through a coarse wire grating which cuts the tough jelly into slender sticks 10 to 14 inches long and about one-eighth of an inch thick. The strips of kanten jelly are then frozen, either by placing them in a refrigeration room at a temperature between —5° and —15° C., or by allowing them to remain outdoors on a cold night. The freezing causes the water to crystallize out, so that when the kanten thaws, most of the water runs out, taking with it the substances which are soluble in cold water. This leaves the gelose in a relatively pure condition. After thawing, the kanten is left to dry in the sun. When entirely dried the thin sticks, called slender kanten, are trimmed to uniform lengths and tied into small bundles weighing from one-half pound to three pounds. The thin sticks are about a foot long and an eighth of an inch in thickness. Kanten is also prepared in the form of sheets about a foot long and 1 to 1½ inches wide, and as rectangular blocks about 8 inches long and 1 inch square.



Courtesy Takamine Incorporated.

FIG. 48.—Drying frozen kanten (agar-agar).

If artificial refrigeration is not employed in the freezing of the agar gel, the season during which the kanten can be manufactured is necessarily limited to the winter months. Moreover, fair weather is required for the thawing and drying of the frozen gel; this limits the localities where it can be manufactured.

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Chapter 7.

The Manufacture and Utilization of Alginic Acid and Other Miscellaneous Vegetable Products from the Sea.

Algin.

Alginic acid, or algin, is an organic acid, which occurs in large quantities in many seaweeds having the composition 42.0% carbon, 4.5% hydrogen, 53.5% oxygen. In 1883, Stanford noticed that a viscous liquid formed in the sacks contained in the fronds of certain laminaria when the fronds were soaked in fresh water. When this liquid was expressed and evaporated to dryness, a substance "resembling albumen" remained which was insoluble in pure water, but easily soluble in water containing a small amount of sodium or potassium hydroxide or carbonate. Stanford[1] named the colloidal substance which was soluble in the dilute soda solution, algin or alginic acid. Stanford recognized the commercial possibilities of this substance and its derivatives and carried out extensive investigations to determine the properties and possible uses of alginic acid and alginates. Later he commenced manufacturing it on a commercial scale in Scotland. However, the process was not successful commercially. Evidently a high enough price could not be obtained for alginic acid or the alginates to make their manufacture commercially profitable. The kelp plant of the Hercules Powder Company, which manufactured solvents and potash from the giant kelps of the Pacific Coast near San Diego, California, during the World War, utilized the portion of the kelp plant which remained after the fermentation process for the manufacture of sodium alginate.

The Chemical and Physical Properties of Algin and Sodium Alginate.

Alginic acid is insoluble in cold water and but slightly soluble in boiling water. It is insoluble in alcohol, ether and glycerol. Moist alginic acid is capable of absorbing 200 to 300 times its weight of water. When moist it is readily soluble in dilute alkali, but when dried it becomes very hard and horny and resistant to solvents. The dried alginic acid can be turned on a lathe.

Upon acidifying a solution of sodium alginate with a strong mineral acid, free alginic acid is liberated and, being insoluble in water, it precipitates as a white gelatinous mass.

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[1] *Chem. News, 47* (1883), 254-7 and 267-9.

Sodium alginate in solution is coagulated by ethyl and methyl alcohol and acetone.

Solutions of sodium alginate are transposed by solutions of the salts of the following metals, insoluble alginates being formed: cobalt, copper, platinum, nickel, silver, bismuth, antimony, zinc, cadmium, aluminium, chromium, uranium, barium, calcium and strontium. Insoluble alginates are also formed by solutions of the following salts: stannous and stannic chloride, mercurous and mercuric nitrate, ferrous sulphate and ferric chloride and lead acetate. A solution of sodium alginate is not precipitated nor coagulated by alkalies and salts of alkalies, including lithium, alkaline silicates, and potassium bichromate; sodium stannate, succinate, biborate and tungstate; magnesium and manganese salts, starch, glycerol, sucrose, amyl alcohol; boric, acetic, carbolic, tannic, butyric, benzoic, gallic, pyrogallic, arsenious and succinic acids; mercuric iodide and chloride; bromine, iodine and chlorine.

TABLE 25

METALLIC ALGINATES *

Soluble Alginates † (Precipitated by Alcohol)

Metal	Salt Used	Character of Precipitate	
Li	Li (acetate)	Silver white	Gelatinous, transparent
Na	NaOH	White	"Stringy," brittle when dry
Mg	Mg (acetate)	do.	Transparent, gelatinous
NH_4	NH_4OH	Light yellow	Light, gelatinous
K		Transparent	Light, fluffy
Insoluble Alginates (Precipitated from Acetic Acid Solution)			
Al	$AlCl_3$	White	Gelatinous, brittle when dry, brown color
Ca	$CaCl_2$	do.	Gelatinous, glossy when dry
Cr	$Cr(NO_3)_3$	Light blue	Heavy, nongelatinous
Mn	$Mn(C_2H_3O_2)_2$	Light red	Gelatinous, good gloss to paper when dry
Fe''	$FeSO_4 \cdot 7H_2O$	Light brown	Gelatinous, brittle when dry
Fe'''	$FeCl_3$	Brown	Gelatinous
Co	$Co(NO_3)_2$	Reddish	Gelatinous, good gloss to paper when dry
Ni	$NiCl_2$	Light green	Gelatinous
Cu	$CuSO_4$	do.	do.
Zn	$ZnSO_4$	Colorless	Gelatinous, silvery gloss to paper when dry
Sr	$Sr(NO_3)_2$	Light brown	Heavy, gelatinous, transparent when dry
Ag	$AgNO_3$	White	Gelatinous, becomes dark red when dry
Cd	$Cd(NO_3)_2$	Colorless	do.
Sn''	$SnCl_2H_2O$	White	Thick, gelatinous
Sn''''	$SnCl_4$	do.	do.
Ba	$BaCl_2$	do.	Gelatinous, good gloss to paper when dry
Pt	$PtCl_4$	Light brown	Gelatinous
Au	$AuCl_3$	Red	do.
Hg'	$Hg_2(NO_3)_2$	White	Dense, white, gelatinous
Pb	$Pb(C_2H_3O_2)_2$	Colorless	Gelatinous, like isinglass when dry
Bi	$Bi(NO_3)_3$	White	Gelatinous
U	$U(SO_4)_2 \cdot 4H_2O$	Yellow	Thick, gelatinous

* From Hoagland, D. R., "Organic Constituents of Kelp," *J. Agr. Res.*, *4* (1915), 39-58.

† All these soluble alginates give more or less gloss to paper.

TABLE 26

ALGIN CONTENT OF VARIOUS ALGÆ

(Water free basis)

Alga		% Algin
Macrocystis pyrifera, leaves	Average, 20 samples	16.2
Macrocystis pyrifera, stems	Average, 20 samples	18.2
Nereocystis leutkeana, leaves	Average, 4 samples	14.4
Nereocystis luetkeana, stems	Average, 4 samples	13.6
Pelagophycus porra, leaves	Average, 2 samples	16.1
Pelagophycus porra, stems	Average, 2 samples	15.9
Egregia lævigata, entire plant	Average, 2 samples	18.7
Egregia menziezii, entire plant	Average, 3 samples	19.1
Laminaria andersonii, entire plant		22.8
Iridæa sp., entire plant		1.0
Laminaria digitata, stem		33.3
Laminaria digitata, leaves		31.9
Laminaria stenophylla, stem		39.2
Laminaria stenophylla, leaves		40.1

Sodium alginate solutions are not coagulated by heat nor gelled by cooling. It can easily be distinguished from gelatin since it is not precipitated by tannin.

Stanford[2] gave the composition of alginic acid as being carbon 64.985%, hydrogen 5.700%, oxygen 25.020%, nitrogen 1.995%, and ash 2.30%. He assigned the formula $C_{76}H_{80}N_2O_{22}$.

Krefting[3, 4, 5, 6, 7, 8] prepared a "tang acid" similar to the alginic acid of Stanford but claimed that his preparation was nitrogen free.

Hoagland and Lieb[9] have shown that Stanford worked with very impure materials. Hoagland and Lieb found its composition to be represented by the formula $C_{21}H_{27}O_{20}$. Moreover, they found that upon hydrolysis a sugar was formed which closely resembles l-xylose.

Processes of Manufacturing Algin.

Stanford's Process.

The manufacture of algin is carried on in connection with the manufacture of iodine and potash, for algin itself has never been considered of sufficient value to justify its preparation from seaweed unless other products could also be obtained in the process.

Stanford originally suggested its manufacture to enable the Scotch iodine factories to compete with the South American iodine industry. His process may be described as follows: Drift-weed (consisting chiefly of *Laminaria digitata* and *Laminaria stenophylla*) is macerated, with or without heating, for twenty-four hours with one-tenth of its weight of sodium carbonate. At the end of this period, the plants are completely disintegrated. A very viscous, semi-gelatinous mass is obtained which is difficult to filter. If the solution is cold it is then heated gently to permit its filtration through coarse filter bags. Cellulose, sand, etc., remain in the filter bags. The alginic acid is precipitated from the solution by the addition of either sulphuric or hydrochloric acid. The alginic acid precipitates in light gray albuminous flocks, and is filtered from the solution in a filter press and washed. It forms a compact cake resembling new cheese. It may either be sold in this condition or it may be dissolved in sodium carbonate solution. The solution is then partially neutralized with hydrochloric acid and dried on trays in a drying room provided with a current of air. Thus obtained, the sodium alginate is in the form of thin, almost colorless sheets, resembling gelatin but very flexible.

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[2] *J. Soc. Chem. Ind.*, *5* (1886), 218-221.

[3] Eng. Pat. 11,538 (1896), abs. in *J. Soc. Chem. Ind.*, *15* (1896), 720.

[4] Eng. Pat. 12,277 (1898), abs. in *J. Soc. Chem. Ind.*, *17* (1898), 794.

[5] Eng. Pat. 12,416 (1898), abs. in *J. Soc. Chem. Ind.*, *17* (1898), 846.

[6] Eng. Pat. 13,289 (1898), abs. in *J. Soc. Chem. Ind.*, *17* (1898), 846.

[7] Eng. Pat. 8,042 (1899), abs. in *J. Soc. Chem. Ind.*, *19* (1900), 361.

[8] *Biochem. Centralblatt*, *8* (1909), 770.

[9] *J. Biol. Chem.*, *23* (1915), 287-297.

The filtrate from the alginic acid is evaporated and carbonized. The iodine and potassium salts are recovered from this char according to the procedure followed in the manufacture of iodine from kelp (see page 77).

The substance, which does not dissolve when the fresh seaweed is treated with the sodium carbonate, is left as a residue after the first filtration. Stanford has named it algulose or algic cellulose. It contains no fiber, but consists of fine cellular tissue which according to Stanford makes a transparent and very tough paper. Algulose dries to a very hard dense mass which may be used for the manufacture of buttons, knobs, etc.

By this process Sanford[10] claims to be able to utilize 70 per cent of the air dry seaweed. His figures for the materials recovered from 100 tons of air dry laminaria by this process (wet process), the destructive distillation process and the old kelp process are given below:

Kelp Process
Per Cent Utilized, 18

Kelp, 18 tons	Salts, 9 tons Iodine, 270 lbs.	Residuals—kelp waste 18 tons, valueless

Destructive Distillation Process
Per Cent Utilized, 36

Char, 36 tons	Salts, 15 tons Iodine, 600 lbs.	Residuals—charcoal 36 tons, tar and ammonia

Wet Process

Water extract, 33 tons	Salts, 20 tons Iodine, 600 lbs.	Residuals—algin 20 tons, cellulose 15 tons dextrin, etc.

Hercules Powder Company's Process.

In Chapter 5 the Hercules Powder Company's fermentation process for the manufacture of solvents and potash from the giant kelps was described (page 108). They utilized that portion of the kelp which was not disintegrated by the fermentation process for the manufacture of algin. The process involved the same general steps as the process just described. The kelp residue was treated with sodium carbonate solution until the tissue was disintegrated. After filtration, the solution was acidified; this precipitated the alginic acid which was filtered from the solution. Sodium alginate was prepared by dissolving this precipitate in caustic soda or sodium carbonate.

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[10] *J. Soc. Arts, 32* (1884), 717-730.

Uses of Alginic Acid and Alginates.

Alginic acid as such is comparatively limited in its applications. Since it can be molded while wet and retains the form when dried, it can easily be made into any desired shape. When dry it assumes a hard, horn-like form that is very insoluble and resistant to the action of chemicals. It may be used as a substitute for horn and as an insulating material.

The table of properties (Table 25) of the various alginates points out many uses. Sodium alginate is the most useful of the alginates, since it is easily soluble in water and can be made into insoluble substances readily. Thus it is a valuable sizing material. It possesses many advantages over starch as a sizing material; it fills the cloth better, is tougher and more elastic. Moreover, it is transparent when dry. It imparts to the goods a thick, clothy, elastic feeling without the stiffness imparted by starch. Since its solutions are so exceedingly viscous it goes farther than starch or any gum. Once the sodium alginate has impregnated the cloth it may be made insoluble easily by treatment with dilute acids, lime-water, salts of calcium, barium and various other metals. It may be used for the fixing of mordants in fabrics, and to a limited extent as a mordant. Ammoniated aluminium alginate becomes insoluble after drying and may be used for the preparation of waterproof fabrics.

Sodium alginate solutions dissolve shellac. When the resulting lacquer is dried a tough, tenacious film is formed which, however, is soluble in water. Treatment with dilute acids renders this film insoluble, but its other properties, desirable in a varnish, remain unimpaired.

The alginates of the following metals are soluble in dilute ammonia solutions: silver, copper, cadmium, ferric iron, cobalt, nickel, chromium, manganese, zinc, uranium, platinum and stannous tin. These ammoniated alginates break down and become insoluble when their solutions are dried. This suggests their use as waterproof varnishes.

A brown dye suitable for the dyeing of unmordanted cotton has been prepared by nitrating alginic acid. Various inventors have prepared rubber-algin compounds that possessed unusual properties. One small factory at San Pedro, California, makes such articles as buttons, combs, knife handles; while another manufactures pails resembling those made of vulcanized fiber from the giant kelp.

Other Miscellaneous Vegetable Products from the Sea.

Marine algæ have been used by men since prehistoric times. The American Indians made use of the giant kelps of the Pacific Coast in fishing both as bait and for the making of fish lines. Sea-urchins were caught by means of kelp stems as bait. The long rope-like stipes of the giant kelp *Nereocystis luetkeana* were commonly used as fishing lines by the Indians. These stipes were washed in running water for several days, then partially dried, smoked and knotted together. After stretching they were further dried in the sun. The stretching reduced their size to that of a cod fish line. Such lines were brittle when dry but when wet they were very strong and flexible. Eelgrass was used in basket weaving by the Indians. The long hollow stems of kelp are coiled and used as a worm condenser for distilling "hoochena" by the Eskimos in the preparation of a popular modern Arctic drink.

The most important modern uses of seaweed and marine plants other than those which have been considered are as fertilizer, as animal feed, for sizing, for the manufacture of paper and in upholstering and the making of mattresses. Of these various uses for kelp and seaweed, the use of marine plants as fertilizer is the most general, since some seaweed is used in this way on practically every seacoast.

Seaweed as Manure.

Although the use of the giant kelps of the Pacific Coast as fertilizer has already been considered in some detail in Chapter 5, the use of other seaweeds as manure is of such importance that it should be given special consideration. For many centuries seaweeds have been used to increase crop yields in Japan, China, Great Britain, France and many other countries that have a considerable extent of seacoast. When the beneficial results of the addition of water soluble potassium compounds to growing crops was discovered, it explained in a large measure the advantages derived from the use of seaweeds and seaweed ashes, for these substances usually contain relatively high percentages of potash.

The use of seaweed as manure is the most universal use to which it is put; and in some countries, the main use which is now made of algæ is as manure. In Great Britain since the potash, iodine and edible seaweed industries have declined rapidly during recent years, the use of seaweed as fertilizer has become the most important seaweed industry. No statistics relative to the amount of seaweed used as manure are available, since the weed is rarely sold or transported for long distances. The algæ are usually collected by the farmers in the vicinity of the seacoast and applied by them to their land. Some seaweed is gathered in the New England States but the use of seaweeds, other than the giant kelps, for fertilizer in the United States has always been only of minor importance. Evidently this is because America possesses a great abundance of other more easily accessible fertilizing materials.

Composition and Value of Seaweeds as Manure.

Many analyses of seaweed have already been given in Tables 6, 7, 9, 11, 17, 18, 19, 22, and 24. These analyses indicate that, in addition to the relatively high potassium content, the dry matter of seaweeds contains from 1.0 per cent to 7.0 per cent of nitrogen. In most common seaweeds the amount of nitrogen in the dry matter varies between 2 and 3 per cent. Much smaller amounts of phosphorus calculated as phosphoric acid (P_2O_5) are present; the maximum amount is about 1.0 per cent and the minimum about 0.2 per cent of the weight of dry matter. The total amount of fertilizing constituents present in the fresh seaweed is comparable to the amount present in barnyard manure. However, seaweed contains a much greater amount of potassium salts, and a much smaller amount of phosphoric acid. Seaweed contains about the same amount of nitrogen as barnyard manure.

For certain root crops such as beets and potatoes the use of seaweed as fertilizer is particularly desirable, since these root crops need larger proportions of potash than most other crops. Since seaweed is especially low in phosphorus, and relatively low in nitrogenous constituents, materials high in these substances should be mixed with it, if a complete, balanced fertilizer is desired.

Nearly all of the potash contained in seaweed is in a water-soluble form and is therefore immediately available for plant use. The nitrogen and phosphoric acid which it contains only become available when the seaweed decays. This takes place relatively slowly in the soil. Thus it is not especially valuable as a top-dressing, as it contains little water soluble or readily available nitrogen. If it is mixed with barnyard manure before its application it decays more rapidly when it is applied and thus the nitrogen and phosphorus become available more quickly.

The analyses given (Tables 6, 7, 9, 11, 17, 18, 19, 22, and 24) point out that all seaweeds are not of equal value as fertilizing materials. The chief algæ collected on the European coasts for use as manure are *Fucus nodosus, F. vesiculosus, F. serratus, Laminaria digitata, L. saccharina, L. stenophylla* and *Rhodymenia palmata.* Of these the laminaria and *Rhodymenia palmata* are more valuable for fertilizer than the fuci. The harvesting of these weeds has been described in Chapter 4 and this will not be repeated here. The weeds are always more or less mixed as they are harvested, so it is rather difficult to place any definite value on any particular load of seaweeds. However, in general, it may be said that seaweed as it is harvested has about the same value per ton as farmyard manure. It should be supplemented with a phosphatic fertilizer if a complete, all-round fertilizer is desired. It is especially valuable for root crops and for clover because of its high potash content. Its one particular advantage over manure is its freedom from weed-seeds and fungous diseases.

Algæ Used for Stock Feed.

In Norway, Scotland and Ireland, herds pasturing along the seashore graze on the fuci exposed at low tide. In Norway and Scotland, Irish moss and various rockweeds are gathered, boiled and mixed with meal which is fed to horses, pigs and cattle. Cattle and horses are not usually fond of seaweeds, however, unless they are used to eating them. As a class seaweeds are considered poor animal feeds since they are not readily digested and are not liked by the animals. Consequently, they are seldom fed where hay and other feeds are plentiful.

Recently, however, there have been attempts to manufacture chicken and stock feed from the rockweeds. A "seaweed meal" has been put on the market at Harsted, Norway, which is prepared by drying and grinding wrack (*Fucus vesiculosus*). This feed contained approximately the following materials:

Water	6.5%	Protein (N × 6.25)	7.0%
Ash	19.1	Crude fiber	6.2
Ether extract	2.8	N-free extract	58.5

This feed contained too much inorganic matter.

A process has been proposed in Denmark whereby the seaweed is partially digested in the process of manufacture. The wrack is thoroughly washed to remove as much of the soluble salts as possible. The washed plants are cooked with superheated steam, drained and then pressed into cakes, which are dried in a vacuum and ground into a coarse powder. The juice formed during the cooking process is evaporated until a portion of the salts crystallize out. The crystals are separated from the mother liquor in a centrifugal separator. The mother liquor is mixed with the powdered cake and the mixture pressed into cakes. The analysis of the feed is as follows: water, 5 per cent; protein (N × 6.25), 13.12 per cent; crude fiber, 9.0 per cent; ash, 5.03 per cent.

Seaweeds Used in the Sizing of Cloth.

The chief seaweed products which are used in the preparation of sizes are Irish moss, funori and agar-agar. The first two mentioned are the only ones generally used, as agar is too valuable to be used in the sizing of any but the more expensive fabrics, such as silk.

The curing of Irish moss has been described in Chapter 6 and its properties have already been considered. The chief disadvantage in the use of Irish moss is the difficulty that is encountered in getting the dried moss into solution, 3 to 5 hours' boiling being required. Field[11] has shown that Irish moss can be prepared in an easily soluble form by evaporating a solution of the moss to dryness in a vacuum, but this method has not been adopted commercially.

In regard to the use of Irish moss as a sizing material, Stocks and White[12] say:

> There is no doubt that if Irish moss could be obtained in sufficient quantity and a clear solution of it easily prepared, it might be much more used than it is. There are some sizing materials sold that are made up of it, but we have not found it to be extensively used; the amount of salt in it is a drawback, producing a harsh feel on the yarn, but this might be removed by a preliminary steeping in water.

Irish moss is used as an ingredient in kalsomines, shoe stains, shaving soaps, and cosmetics. It is also mixed with dye solutions to thicken them for use in the printing of calico. A process of treating Irish moss extract with formaldehyde, in order to make the dried size insoluble, has recently been patented.

[11] *Bureau Fisheries, Ec. Cir. 51* (1921).

[12] *J. Soc. Chem. Ind., 22* (1903), 4-12.

Funori.

Funori is the name given to a sizing material made principally from *Gloiopeltis coliformis* and *G. intricata*[13] by the Japanese.

The manufacture of this sizing material is one of the important seaweed industries of Japan. There are over a hundred funori factories in Japan which now manufacture about a million dollars worth of "seaweed glue" annually. Osaka is the principal manufacturing center of the industry.

The value of funori produced in Japan[14] during the years 1909-1918 is given below:

1909	$193,419	1914	$386,602
1910	240,062	1915	304,517
1911	239,037	1916	569,727
1912	210,435	1917	655,881
1913	398,479	1918	1,232,911
		1919	576,900

These figures show how rapidly this industry has grown during recent years.

Gloiopeltis grows chiefly on rocks in shallow water on the Pacific shores of the Japanese islands. It is gathered from the rocks by means of long-handled hooks and rakes, or by divers. The men who gather the weed spread it on the beach to dry. The dried algæ are sold to the funori factories.

The first step in the manufacture of funori is the sorting and cleaning of the algæ. The washed algæ are soaked in fresh water and then drained and spread out in thin layers on straw or rush mats, or tightly packed in shallow bamboo trays in such a manner as to form a thin sheet of funori in the bottom of the tray. The sheets are turned out on matting to bleach and dry in the sun. The sheets are sprinkled about every ten minutes to aid in the bleaching and to prevent the curling of the sheets of funori. When the sheets are completely bleached, indicated by the exudation of a sticky juice, they are dried and packed in bundles. The sheets of this sizing material are loose-meshed, thin and flexible. Some of the bundles are rolled up like Japanese matting, forming a roll three feet long and about six inches in diameter.

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[13] Other species of algæ used for the manufacture of funori are the following:

Mukade-nori (*Grateloupia ficilinus*) is found growing abundantly on the coasts of Shikoku, Kiushui, Kii and Shima. It attains a length of 3 or 4 inches.

Kotoji-tsunomata (*Chrondrus etatus*) is an alga, very similar to Irish moss, which is found in Kazusa, Shimosa, Izu and Hitachi.

Ginnanso (*Iridæa sp.*) is found in the North of Hondo and Hokkaido.

Tamba-nori (*Grateloupia sp.*) is found chiefly in Owari, Mikawa, Shima, Kii and Echizen.

Tobera (*Chrondrus sp.*) grows on the coasts of Sado, Izumo, and Iwami. It attains a length of about ten inches.

Saimi (*Gymnogongrus sp.*) is found in Izu and the Shichishima Islands and attains a length varying from one to four inches.

Yanagi-funori (*Gloiopeltis tenax*) grows on all the Japanese coasts but is chiefly found around Hizen and Itsushima. This weed makes an exceptionally fine grade of funori that is chiefly used for the sizing of silk textiles.

[14] *Résumé Statistique de l'Empire du Japon, 36th yr.* (1922).

When species like ginnanso (*Iridæa sp.*) or tsunomata (*Chrondrus sp.*) which have large and tough fronds are used, they are soaked for some time and then steamed to render them more pliant. Afterwards the steamed seaweeds are chopped up with hand knives and spread out to bleach. The remainder of the process is the same as in the case of *Gloiopeltis coliformis.*

The manufacture of funori is carried out only in the summer months, but care must be taken that the water used for washing it is not too warm.

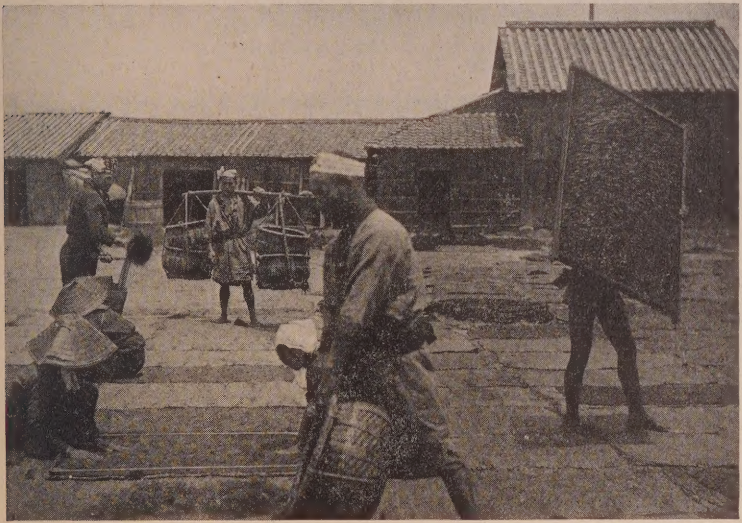

FIG. 49.—The manufacture of funori (seaweed glue); spreading the kelp out to dry.

Uses of Funori.—Funori is readily converted into a size by dissolving in boiling water. Its principal uses are as a substitute for starch in laundering, for sizing cloth, paper and for the preparation of kalsomines. Some funori is exported to Europe, where it is used for the sizing of cloth.

Marine Plants Used for the Making of Mattresses and Upholstery.

Eelgrass or seagras (*Zostera marina*) finds extensive use in the stuffing of mattresses and furniture. This plant is unlike all the seaweeds that have been considered in previous chapters for it does not belong to the group of plants known as the marine algæ but to the *Naidaceæ* or pond-weed family. It derives its name from its grass-like appearance.

Eelgrass thrives only on muddy bottoms in shallow water in protected places.

Important eelgrass industries exist in Great Britain, France and

Holland. The exports of this material from Holland aggregate 2,000 to 3,000 tons annually.

The grass is mowed by men with scythes at low tide. It is necessary for the mowers to work in the water as the grass does not grow above the low water mark. The cut grass is spread in adjacent fields to dry. When it is partially dried and has become black it is soaked in ditches filled with fresh water for several days. It is again spread on the fields, and when completely dry, it is taken to the warehouses where it is pressed into bales of about 100 pounds each. The blacker the cured grass the higher the price obtained for it.

Eelgrass prepared in this way is used as a substitute for hair in the filling of mattresses and upholstering furniture.

Odd Uses for Seaweeds.

Many processes of manufacturing paper from this eelgrass (*Zostera marina*) have been suggested. It contains a relatively small amount of fiber but the paper produced from it is of very good quality. The process of manufacturing paper from eelgrass is almost the same as that used in the manufacture of paper from esparto; however, the zostera contains less foreign matter and is, therefore, more easily bleached.

At various times, processes of manufacturing paper from the true marine algæ have been proposed but none of these processes have been adopted commercially. Excellent paper has been prepared from the giant kelps of the Pacific Coast by Andrews[15] and others.

Many species of algæ are used by the Japanese for decorative purposes. The most important species used in this manner are *Sargassum enerve* (called moku or mo by the Japanese) and other species of *Sargassum, Ecklonia bicyclis, E. cava,* and various species of *Laminaria. Sargassum enerve* becomes an attractive green color when it is dried, and on New Year's day is intertwined with *Laminaria radicosa* and used in the decoration of Japanese homes in much the same way that holly is used by the Europeans and Americans.

In certain parts of the world certain species of seaweed are extensively used in the manufacture of ornaments and curios. Various species of laminaria which have a hollow stipe are used for knife handles as these seaweeds dry to a very hard, wrinkled, hornlike substance which possesses an attractive appearance. The giant kelp, *Macrocystis pyrifera,* has been used in the preparation of a hard substance resembling ebonite or vulcanized fiber. In the preparation of this material the salts are washed off and the kelp is highly compressed and dried.

A submarine plant known as *Posidonia australia* found on the southern coast of South Australia, particularly in Spencer and St. Vincent gulfs, contains a valuable fiber which is adaptable for the manufacture of cloth, rope, twine, mats, paper and stuffing. *Posidonia australia* does not belong to the marine algæ as it has greenish flowers and fleshy fruit about the size of an olive. The commercially important part of the plant is the fibrous remains of the leaf sheaths that cover the base of the stem. These fibers are longer and finer than those of *Posidonia oceanica,* the only other species of the genus known, which is found in the Mediterranean and along the European Coast of the Atlantic. The quantity of the fiber in the deposits on the South Australian coast is very large. In Moonta Bay, South Australia, the deposits cover many square miles reaching to a depth of nine feet or more. The chief difficulty in the preparation of the fiber is the separation of a large proportion of waste matter raised with the fiber in digging it from the beach.

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[15] Cameron, F. K., *J. Frank. Inst., 176* (1913), 347-83.

Various investigators have prepared the sugar, mannite, from certain species of laminaria and have proposed using these seaweeds as the source of the manna of commerce. *Laminaria saccharina* contains 12 to 15 per cent of this sugar. In Kamschatka the natives prepare an alcoholic drink from the dulse (*Rhodymenia palmata*). Other unusual products that have been made from marine algæ are duplicator rolls and rubber compounds.

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Chapter 8.

Pearls and the Pearl Industry

By GEORGE FREDERICK KUNZ.*

The pearl is one of the most precious, costly, richest, and most beautiful of all objects of human adornment. For over twenty-five centuries classed with the precious stones, it is not of inorganic origin as are the others. This animal substance formed in the fleshy part of the pearl oyster must have inspired Gray [1] to write:

"Full many a gem of purest ray serene
The dark unfathom'd caves of ocean bear;"

Many a peerless gem still dwells in the deep unfathomed ocean, for probably the most precious may have escaped the pearl-diver, as they may rest even beyond the greatest depths that the divers can reach.

But when found such a gem merits the charming lines at the beginning of Keats' Endymion:

"A thing of beauty is a joy forever."

For when it is just taken from its pearly gates it is at the moment of its greatest beauty.

Historically Important Pearls.

While there is a lack of evidence that pearls, or pearl shells, were used ornamentally to any considerable extent in early Egypt, some remains of them, which may date from 3,000 B.C., have been found in the tombs. From the fifth century B.C. more seem to have been made use of, but it was not until the age of the Ptolemies that they were used in lavish abundance. The Old Testament offers us in our English version one solitary mention of pearls (Job, chap. xxviii, verse 18), but the Hebrew word so rendered certainly did not designate these gems. Among the ancient Persians they were known and prized as early as the fourth century, and probably much earlier; the Babylonians and Assyrians also valued them and used them as ornaments. In the Greek dynasties founded by Alexander's generals after his death in 323 B.C., they gained rapidly in favor, a noted instance being the great pearl of Cleopatra which she is said to have dissolved and swallowed at the splendid banquet she gave to Mark Antony. In Imperial Rome, pearls were the most prized gems. An echo of this may be seen in the New Testament parable of the "Pearl of Great Price."

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[1] Gray, Thomas, "Elegy in a Country Churchyard."

The greatest historic pearls, with their weight in pearl grains computed according to the present standard carat of 200 milligrams, making a pearl grain of 50 milligrams, are as follows:

	Weight in Pearl Grains
Gomara Pearl, found in Gulf of Panama in 1515	127.29
Oviedo Pearl, found in Gulf of Panama in 1515	106.75
"La Peregrina" of Philip II, found at Panama in 1560	137.55
Pearl of Charles II of Spain (1611-1700), about the size of "La Peregrina"	137.55
The Gogibus Pearl, brought from the West Indies in 1620, to Philip IV of Spain, by François Gogibus of Calais	517.36
Rudolph II's Pearl (1552-1612)	123.18
Shah Sofi's Pearl, seen by Tavernier about 1650 (estimated)	513.25
Shaista Khan's Pearl, seen by Tavernier about 1650	225.83
Great Pearl of Shah Jehan's Peacock Throne (estimated)	205.30
"La Reine des Perles" of French Crown Jewels	112.15
"La Pellegrina" of the Russian Zosima	114.45
"La Régente," given by Napoleon to Josephine	345.93
The Hope Pearl, a drop-shaped baroque	1887.70
Tiffany Queen Pearl, found in New Jersey	95.46
Mme. Nordica's abalone pearl	179.64

Of Cleopatra's twin pearls, Pliny says nothing as to the weight or value, but he tells us that the companion pearl of the one dissolved at Antony's banquet was taken to Rome after Cleopatra's death in 31 B.C., where it was cut in two halves, which were attached to the ears of Venus at Rome in the Pantheon. The French writer Budé of the time of François I (1515-1547) estimated that this pearl must have been worth 25,000 gold crowns, or about $56,000.

In the inventory of the Russian Crown Jewels, lately issued by the Soviet Government, the following remarkable pearl jewels are listed:

Necklace of 38 pearls, weighing in the aggregate 2260 metric grains, an average weight of 60 grains.

Brooch set with two pearls of extraordinary size, one weighing 308 metric grains, the other 152 metric grains.

Noted American Pearls.

The most remarkable exhibit of pearl jewelry that was ever seen in the United States up to that time, was shown in 1893, at the World's Columbian Exposition [2] in Chicago. The collection embraced four necklaces, which for their purity of color, fine orient, even form and careful selection were unsurpassed, especially notable among them being the necklace of 3 strands, consisting of 159 pearls, and a simple strand of

[2] Kunz, George Frederick. *U. S. Fish Comm. Bull., 13* (1893), 441.

44 pearls, weighing 946¾ pearl grains (971.84 pearl grains metric). Each of these strands was at that time considered to be worth $100,000, and they would command a still higher price today. Possibly even more remarkable for their great size were the 38 pearls constituting another strand, and weighing in the aggregate 1,092.20 grains metric, and the strand of 52 pearls weighing 1,175.85 metric, in all worth over $1,000,000.

Importance of Industry.

The following is a careful estimate of the number of persons employed in the pearl fisheries of the world:[3]

Asia	
Persian Gulf	35,000
Ceylon	18,000
India	1,250
Red Sea, Gulf of Aden, etc.	3,000
China, Japan, Siberia, etc.	20,000
Total	77,750
Europe	
British Isles	200
Continent of Europe	1,000
	1,200
Islands of the Pacific	
South Sea Islands	4,500
Australian Coast	6,250
Malay Archipelago	5,000
	15,750
America	
United States Rivers	8,500
Venezuela	1,900
Mexico	1,250
Panama	400
Miscellaneous	1,000
	13,050
Grand Total	107,750

From 1891 to 1908, inclusive, the imports of pearls into the United States were valued at $20,120,798. Prior to 1891, pearls were not separately classified, but were included among "jewelry and precious stones."[3] The total pearl imports for 1909 to 1921, inclusive, amounted to $59,499,534, this gives a grand total of $79,620,332, making well over $80,000,000 of pearl imports if we add the comparatively small, and not separately, recorded imports before 1891.

The Origin and Growth of Pearls.

Concerning the origin of pearls it is only necessary to mention as a curious superstition the popular theory given by Pliny and copied from his

[3] Kunz, G. F., and Stevenson, C. H., The Book of the Pearl, New York, 1908.

Natural History by most of the ancient and medieval writers, as well as by the Arabic authors who drew their information from the same source. This was that when the pearl oyster rose to the surface of the water and opened its valves, drops of dew were caught, and these congealed into the form of pearls. However, at least one ancient writer comes nearer to the truth, although he does not attain it. This is the geographer Isidore of Charax, a city near the Persian Gulf, who wrote in the early part of the first century A.D. The text of his works has been lost, but in a fragment of his Parthian Itinerary preserved by Athenæus, we read that pearls were engendered by something that adhered to the flesh of the oyster. In a curious vein he continued: "It grows in the mouth of the oyster and has claws and brings in food. It is a small crab and is called 'guardian of the oyster.' Its flesh penetrates through the center of the shell like a root; the pearl being engendered close to it, grows through the solid portion of the shell and keeps growing as long as it continues to adhere to the shell."[4] In view of the modern explanation that the pearl is built up around the body of an intrusive trematode, this shows that Isidore of Charax probably had access to fairly accurate information on the subject.

Modern theories as to the formation of pearls may be said to date from the sixteenth century at least, for in 1554 the French naturalist Rondolet[5] declared that pearls were diseased concretions occurring in the mollusca, similar to the morbid calculi in the mammalia. The similarity in structure and composition of the pearl and the pearl shell was confirmed by Réaumur (1683-1757) from microscopic examination of cross sections which showed concentric layers similar except in curvature, in the shell and the pearl. Finally, the Italian naturalist, Filippi, observed that many of the pearl formations were associated with the presence of a trematode or parasitic worm which he named *Distomum duplicatum* and which he proclaimed in 1852 to be the original cause of the pearl. This theory was elaborated and confirmed by Küchenmeister in 1856, by Möbius in 1857, and by other investigators. Prominent among these were E. F. Kelaart and his assistant Humbert who, in 1859, disclosed the important relation which the presence of such organisms bore to the origin of pearls in the Ceylon oysters. The chief exponents of this view in later times have been Raphael Dubois and Professor H. L. Jameson. The latter found that the trematode entered the mussel as a tailless cercaria, and at first may often be found between the mantle and the shell. After a time the larva comes to rest in the connective tissue of the mantle and assumes a spherical form. It soon dies and the tissues form a structureless mass which the pearl oyster covers with successive layers of nacre, and which becomes the nucleus of the pearl.

A still more recent theory has been ably presented by A. Rubble.[6] Although his investigations were principally carried out with fresh-water mussels, the general conclusions seem equally well applicable to the marine mollusks. He found that the nuclei of the pearls consisted of particles of a yellow-brown substance, which was strongly refractive. The same substance was found in the connective tissue of the mantle as well as in its shell secreting epithelium, and it appears to be related to that of the periostracum or outer layer of the shell. The theory is that these granules act as stimulants or irritants, provoking the deposition of nacre, just as do the trematode invaders whose presence as nuclei has undoubtedly been proved in the case of many marine pearls. Thus we are gradually led to the conviction that the causes of pearl production are various, the essential point being the presence of an irritating granule, either resulting from the decomposition of an organism, or else generated in the mantle of the pearl-oyster as material for the outer shell, and which, failing to be utilized in this way, becomes a source of irritation to the tender mantle and is provided with a nacreous coating.

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[4] Schoff, Wilfred H., Parthian Stations of Isidore of Charax, Philadelphia, 1914, 11.

[5] Universæ Aquitilium Historiæ Pars Altera, Lugduni, 1554.

[6] "Concerning the Formation of Pearls, etc., *Margaritana Margaritifera*" (German), *Zoologisches Jahrbuch* (Anat. Abt.) *23* (1911).

The Composition and Properties of Pearls.

Structure.—The lustre or "orient," for which the true pearl is famous, results from the structural arrangement of the surface as well as the quality of the material. As a rule the nacreous coating is deposited in exceedingly thin layers; these laminæ overlap one another, the surfaces appear crumpled and corrugated when viewed through the microscope, and the edges form serrated outlines. The greater the angle which the laminæ form with the surface, the closer will be these serrated outlines, and where the plane of the exterior laminæ is parallel with that of the surface, the lines are not present. This disposition causes the waves of light to be reflected from different levels on the surface, just as in a soap bubble, and the minute prisms split the rays up into their colored constituents, producing the chromatic or iridescent effect.

Composition.—The composition of pearls is chemically identical with that of the nacreous covering of the pearl-shell, the so-called "mother-of-pearl." In each case, an average of many analyses has shown the presence of about 91.72 per cent of carbonate of lime, 5.94 per cent of organic matter, and 2.34 per cent of water. The specific gravity is about 2.75 for the compact shell, becoming greater as the deposit of nacreous coatings increase, and the hardness is close to 4.

Preservation.—A due amount of care is requisite for the preservation of pearls. In the case of necklaces, they should be restrung every three, six or twelve months, the proper time being determined by stretching the thread. If it can be seen between the pearls, so as to give the impression that a pearl is missing, restringing is necessary, for a newly-strung necklace is taut.

Strands of pearls should never be dipped into water or solutions of any kind, because the string which joins them might absorb the liquid into the pearl, thus permeating the concentric layers so as to discolor the gem.

Although pearls possess a considerable degree of hardness, they should not be subjected to rough usage. In cleaning, they should first be rubbed with a cloth dipped in alcohol diluted with warm water, or else in a weak solution of soap and water. Then another cloth should be dipped in clean water, and the pearls should be rubbed with this until they are dry. It is important that they should not be left wet. Either salt, rice, pearl powder, or some exceedingly soft substance, may aid in cleaning them, but no abrasive, such as ground pumice, carborundum, or any powder that is sold as a polishing powder, should be used.

If there be fear that the pearls in a safe-deposit box may dry out so as to injure the organic substance, they can be placed in a piece of linen absolutely free from any chemical, putting with them a bit of blotting paper, or fiber-paper, saturated with water; the whole should be wrapped up in paraffin paper, which will prevent the evaporation of the moisture.

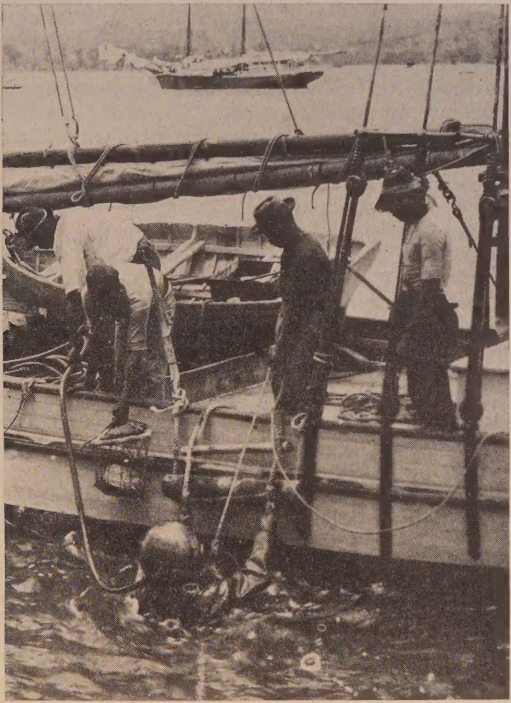

FIG. 50.—Diver, wearing scaphander, is drawn up, his net bag full of pearl shells.

The Fisheries.

Methods.

Shells, thought to contain pearls, are taken either by men diving into the water, or by dredges. Where shells are not plentiful diving is universally employed in the fishery.

Native Diving.—Of the various methods of fishing, the most primitive is direct diving by a naked native. His work must be done very quickly, for he cannot remain under water longer than from 45 seconds to a minute, and at no great depth, for he is confined to depths of from six to eight fathoms. This has been in some places superseded by the employment of white divers incased in scaphanders, which enable them to remain down much longer and to reach a depth of forty fathoms.

Diving Suits.—The diving dress worn by the pearl fishers, properly called scaphander, consists of solid sheet rubber, both sides of which are covered with canvas. The head-piece is of tinned copper, and in it are three glasses, one at the front and one at either side, so that the diver may see as much as possible of his surroundings. A valve which he controls regulates the pressure of the atmosphere. The dress has a double collar, of which the inner part comes up around the neck, while the outer part is hermetically fastened to the breast-plate. The connection of the diving suit with the air-pump is by means of a stout rubber tube, which enters the helmet, and through which the diver's supply of air is pumped. It consists of three or four lengths of light hose, each of about fifty feet, and this is buoyant so that it can be easily pulled along the bottom without danger of becoming caught in the rocks. In case the bottom is exceptionally rough, very strong material is used for the lowest section of the tube. Before descending, the diver coils it loose about his arm so as to avoid a sudden strain or jerk when it is tightened.

When the diver wishes to come up, he closes the escape valve in his helmet. Thereupon the dress fills and distends with air, causing a speedy return to the surface, and he is hauled aboard the tender by means of his life-line.

The most fruitful sources of danger are fouled air-pipes, broken pumps, falling into holes at the bottom, and more especially paralysis from recklessly deep diving. Sharks are really a minor danger, for they are easily frightened off.

Dredging.—Dredges are used in the more up-to-date fisheries where shells are taken in large quantities. They are, however, only practicable on muddy or sandy bottoms, as rocks or coral would be likely either to stop the boat or break the rope.

Persian Gulf Industry.

The pearl fisheries of the Persian Gulf have been famed in history for over two thousand years, and are mentioned by the earliest European travellers to the Orient, notably by Nearchus, one of Alexander the Great's generals, and by the Greek author Megasthenes, who accompanied another of Alexander's generals, the Macedonian Seleucus Nicator, on his victorious expedition to Asia about 307 B.C. Later comes Isidore of Charax, a writer of the first century A.D., and about the same time, or a little later, Pliny says (ca. 75 A.D.):[7] "But the most perfect exquisite pearls are those gathered in the Persian Gulf." The Persian Gulf is nearly 600 miles long and has an average width of more than 100 miles. The oyster beds are scattered over level areas of coral, rock, and sand, with depths ranging from two to eighteen fathoms. The divers, most of them Arabs, rarely descend into deeper water than twelve fathoms, although

[7] *Historia Naturalis* (Natural History) (Latin), 9, Chap. 35.

valuable pearls are to be secured at greater depths. Arabs can remain under water for longer periods than can the Hindus who carry on the Ceylon fisheries. It but rarely happens that a diver is able to remain submerged, in the average depth of seven or eight fathoms, for a longer time than sixty seconds; still this has been stretched out to seventy or eighty or even ninety seconds occasionally and there is a fully authenticated instance of an Arab diver at Manaar, who on April 13, 1887, remained submerged for 109 seconds in seven fathoms of water.[8]

The fisheries are under the direct control of the maritime Arab sheiks, of course subject to the paramount, but rarely exercised control of a British Protectorate.

Bahrein Island is the headquarters of the pearling fleet. Recently this fleet consisted of 3,500 boats, large and small, manned by from three to fifteen or thirty men, so that in all there are approximately 35,000 fishermen. The divers use stones weighing from thirty to fifty pounds each, attached to their feet to bear them down into the water, and although this method of diving is less spectacular than that of the South Sea Islanders, it possesses the advantage of enabling the diver to reach bottom more speedily. In the most prosperous seasons, fifteen or twenty years ago, these fisheries furnished pearls to the value of about $4,000,000 annually. The greater part are shipped by Hindu or Arab merchants to Bombay, whence they are distributed both to the Oriental and the European markets.

The Sheik of Bahrein in the Persian Gulf is said to have a customs revenue amounting to about $400,000 annually, which makes him the richest ruler in this region. In a good year the pearl fisheries under his control may bring in as much as $2,500,000. The best quality of pearl-oysters are those from the banks just north of Bahrein, known as the Adan. These shells weigh from 4 to 7½ pounds per hundred, while shells from other banks weigh only from 3 to 5½ pounds per hundred. It is estimated that some 2,000 tons of pearl shells are shipped to London and elsewhere annually. The name "Lingah shell" applied to these Persian Gulf shells is due to the fact that the first shipment from the Gulf was made from the port of Lingah (Linjah). While no reliable statement can be made regarding the average number of pearls in a given quantity of shells, reports from Bahrein indicate that the value of the pearls exported is about twenty times greater than that of the shells, but these reports must be discounted by the fact that many of the pearl oysters are thrown back into the sea by the divers to save room on board their craft.[8]

Ceylon Fisheries.

The intermittent and uncertain pearl fisheries of Ceylon have ranked second in importance to those of the Persian Gulf. They are carried on in the Gulf of Manaar, an arm of the Indian Ocean, from 65 to 150 miles in width, separating the island of Ceylon from the southernmost part of India. The pearl oyster beds here-known locally as "paars" are situated off the northwest coast of Ceylon and also in the neighborhood of Tuticorin on the Madras coast of the mainland, the Ceylon fisheries being directly controlled by the British Government, while the Madras Government monopolizes those of the mainland. These fisheries are almost, if not quite as ancient as those of the Persian Gulf; they are alluded to in Singhalese records as early as 550 B.C., and Pliny, as well as other ancient authors, wrote of them.

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[8] Information furnished by U. S. Consul Henry D. Baker, Bombay, India.

As a rule the fishery begins late in February or early in March. The important fishery of the five years ending in 1907 was centered at the improvised settlement of Marichchikadde. But few Singhalese participate in it compared with the large numbers who assemble from India, Arabia and elsewhere. In a short time after the official notices have been issued that a pearl fishery will take place at Marichchikadde on the Island of Ceylon, a populous town springs up there with well-planned and lighted streets, and vast numbers of temporary abodes of all sorts. The fishing fleet consists of several hundred boats of various rigs and sizes. The number of persons on each boat ranges from twelve to sixty-five. Of the 8,600 divers employed in 1906, there were 4,090 Arabs. The season is short, only some six or eight weeks at most. The divers work in pairs each pair using a single diving-stone in common and descending alternately.

The following details regarding the Ceylon Pearl Fisheries have been sent by the Commercial Attaché of France in British India, through the National Bureau of Foreign Commerce, in the Ministry of Commerce, to the Paris Chambre Syndicale:[9]

> The Fisheries Service of Ceylon has just proceeded to an inspection of the pearl-oyster banks. It has been found that a new and very important bank exists in an excellent locality, where the young oysters are not exposed to the ravages of the strong rays and other fish which nourish themselves on the mollusks of the great banks. Since fourteen years ago the fisheries have been prohibited, but it is contemplated to reopen them in 1925, or at the latest in 1926.
>
> The principal markets for pearls being in Paris and London, it may be interesting to note that in 1912 the "boom" which caused the price of pearls to double between January and April, had for its main cause, not as was asserted a "corner" in pearls by the Bombay merchants, but the closing of the fisheries of Ceylon, and of the Persian Gulf. The Ceylonese fisheries have always given irregular results. Although in 1863 they supplied pearls worth £56,000, they only gave £10,000 worth in 1874. In 1879 the value of the production was estimated at £29,000; in 1881, at £59,000. In 1887 the output was worth £39,000; in 1890, £17,000, and in 1891, £52,000. Later the company of pearl fishers of Ceylon lost large sums because of the deterioration of the banks where fishing had been carried on without restriction, and where the fish had destroyed all the immature oysters. The closing of the pearl fisheries of Ceylon and of the Persian Gulf, in the latter case due to an epidemic of the pest which visited the fishing populations, provoked a disturbance of equilibrium between supply and demand. The merchants no longer having other source of replenishment than the Sulu Archipelago, near New Guinea, the Australian coast and the Polynesian Islands, there ensued a rapid rise in price. It was then, in 1913, that there was formed in Bombay a powerful syndicate, in which certain French houses had large capital, for the purpose of controlling the pearl market of the Persian Gulf. The Balkan War and the approach of the World War rendered the European banking houses more prudent, and they refused to make advances on consignments of pearls in Paris and London. Only a single Indian bank continued to supply several millions, and this provoked a rather grave banking crisis in the Bombay money market. During the war a ship was lost by sinking and one-third of the year's yield of the Persian fisheries was lost.
>
> At the present time the market enjoys perfect repose, which will not probably

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[9] *Recueil Mensuel des Procès-Verbaux des Séances de la Chambre Syndicale des Négociants en Diamants, Pierres Précieuses et Perles, et des Lapidaires. No. 60,* June, 1922, 990-991.

be broken until the end of the world crisis. However this may be, the announcement of the proximate resumption of the Ceylonese fisheries is an interesting piece of news for the numerous French houses which draw their supplies from Bombay.

Fishing in the Red Sea.

The Red Sea fisheries date back to very ancient times, having been exploited centuries before the Christian era. In later times they were surpassed, but not superseded by those of the Persian Gulf and of Ceylon, but they have continued to be a good source of supply up to the present day. The largest and best known pearl oyster here is the variety identified by Jameson as *Margaritifera Margaritifera erythrœensis;* it is closely related to the large species in the Persian Gulf.

It measures four or five inches across, though occasionally it attains a diameter of eight inches and a weight of three pounds or more. It is distinguished by a dark-green coloring about the edges, and has a more or less greenish hue over the interior nacreous surface. It only rarely yields pearls, but the shells afford good qualities of mother-of-pearl, and the occasional pearls add to the profit of the catch.

The pearling season usually lasts from March or April until the end of May, and it is renewed in September and October. The vessels are either dhows with from forty to eighty men, or the so-called sambuks, sailboats without decks, which have only from six to twenty-five men. The greater part of the crews are Negro slaves.

The Venezuelan Fisheries.

On the coast of Venezuela, the *Margaritifera radiata* is the chief pearl oyster, a species related to that of Ceylon, although slightly larger in size and having a much greater range of coloration, the hues ranging from white to bronze, with an occasional black one. Pearl fishing in these waters under European direction, dates back to 1500 A.D. The islands of Cubagua, Coche, etc., lie near the larger island of Margarita, and constitute a group with it. While the average size of the pearls from this field was rather small, so great a quantity were taken out toward the close of the sixteenth century that the fifth part of their value, the tribute paid to the King of Spain, amounted to more than 15,000 ducats annually. Then the product rapidly decreased. After 1845, there was a revival of the pearl fishing and by 1909, as many as 350 boats were engaged in the enterprise, all small craft of from two to fifteen tons each.

Recent reports indicate that there has been a good yield of pearls from the fisheries of Margarita Island, for currency amounting to 1,000,000 bolivars has been sent thither to provide for payments on pearl purchases. It is hoped and believed that this will help to relieve the economic troubles of the island.

The Panama Fishery.

The richness of the Panama pearl fisheries on the Pacific Coast was made known to the Spaniards in 1526, by Gonzalo de Oviedo, and many of the finest pearls in the Spanish treasury were derived therefrom. As with the Venezuelan source, the production gradually declined, and recently the success depends almost entirely on the value of the pearl shells. The principal reefs and the headquarters of the fishery are at Archipelago de las Perlas, or Pearl Islands, situated from thirty to sixty miles southeast of the Pacific terminus of the Panama Canal. The pearls are of good quality, frequently of large size; they range in color from white to green and lead-gray, and are often greenish-black. The mollusk is much larger than that of Venezuela, and hence furnishes a fine shell.

The Mexican Fishery.

The pearl fisheries on the Pacific Coast of Mexico were reported to the Spaniards in 1522, after the conquest by Hernando Cortés. From a tribe near the present site of Hermosillo, in the State of Sonora, Cortés secured great quantities of the gems, and the location of the pearl reefs was prominently noted on Cortés' map of this coast, made in 1532. In the eighteenth century one of the most successful of the early pearlers of this region, Manuel Osio, is credited with having marketed 127 pounds' weight of pearls in 1743, and 275 pounds in 1744; he is said to have become the richest man in Lower California.[3] In 1868, the yield of pearls was about $55,000. The fishery was then carried on from shore camps or from large vessels, each carrying twenty to fifty divers, mostly Yaqui Indians. The season lasted from May to late in September. The principal species of pearl-mollusk here is the *Margaritifera margaritifera mazatlanica,* which is closely related to the "black-lip shell" of the Australian coast. It is considerably larger than the Venezuelan oyster, averaging from four to five inches in diameter, and sometimes attaining a diameter of seven or even eight inches. Another species has been named *Margaritifera vinesi.* It occurs only in the northern part of the Gulf near the mouth of the Colorado river.

The California Abalone Fishery.

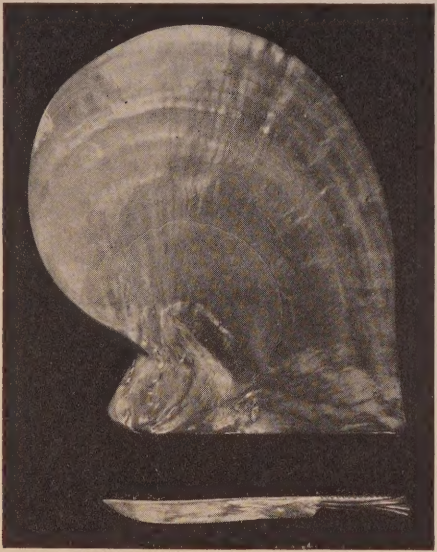
Another valued source for pearls are the abalones (*Haliotidæ*) found on the coasts of California, Japan, New Zealand, and other localities in the Pacific. Although the pearls occasionally found in them have a fine lustre, they are usually of small value, but the shells are valuable for the mother-of-pearl they furnish. In variety and intensity of coloring the nacre is superior to that of the pearl oysters, but it is of less harmonious hue, and the nacreous layer is not so thick and flat.

Many beautiful abalone pearls have been found which were hidden by the closing of the successive valve holes. The so-called "dome pearls" are formed at the tip of the visceral dome.

Some extraordinarily large baroque pearls are found in abalone shells in Lower California. A notable instance was one weighing 393 grams, found in 1921. It is of an elongated pear-shape, and displays brilliant peacock colors. However, only a small number of the abalones contain pearl formations. The finest rarely sell over $50 to $100 each. Many are sold for from $1 to $10 each.

The Australian Fisheries.

Although many fine pearls have been found in the Australian fisheries, they are principally exploited for the pearl shells, and therefore they are described in the section "Mother-of-Pearl." The value of the pearl yield in the northwest Australian fisheries for 1906 was estimated at £50,000, that of the Queensland fishery at £33,000, and that of South Australia at £5,000, a total of £88,000, or nearly $430,000. Relatively few seed-pearls are secured. Some beautiful examples of large pearls have been found, but usually they possess less lustre than the Persian or Indian product, and their form is less regular.



Courtesy American Museum of Natural History, New York.

FIG. 51.—*Margaritifera margaritifera,* a typical pearl oyster shell with outer coating removed.

One of the finest of Australian pearls was that taken by one of the luggers of Messrs. James Clark and Company's fleet near Broome, Northwestern Australia, late in 1917. It weighed 100 grains, was 18 millimeters long, 15 millimeters in diameter, and had a circumference of 45 millimeters. The bottom end was flat for a width of 7 millimeters. This pearl was valued at £20,000.

The Malaysian Pearl Fishery.

The best known of the Malaysian pearl fisheries are those of the Sulu Archipelago, Philippine Islands. Pearls from those fisheries reached the outside world as long as four hundred years ago, and in 1520, Pigopitta, a companion of Magelhaes, reported pearls to be among the prized possessions of the natives. The pearl-oyster reefs extend from Sibutu Pass to Basilan Strait, and roughly cover an area of 15,000 square miles. The large mother-of-pearl oyster, *Margaritifera maxima,* is by far the most abundant, but the Australian "black-lip," *Margaritifera margaritifera,* is also found. Since the Spanish-American War pearl fishing has been the leading industry here.

Other Pearl Fisheries.

Among the pearls which are found in certain other mollusks may be noted the pink pearls sometimes met with in the *Strombus gigas,* the giant conch shell of the West Indies; they are not nacreous and unfortunately do not preserve their hue very well. *Strombus gigas* is one of the largest of the univalve shells, some individuals measuring as much as twelve inches in length and weighing five or six pounds. An exceptionally fine example of a so-called "conch pearl" has been sold in New York for $5,000, the gem having been brought from Nassau in the Bahamas. Pearls are occasionally found in the *Turbinella scolymus,* and in the Indian chank (*Turbinella rapa*) which produces pink and red pearls. The *Pinna squamosa* furnishes some brown pearls of poor quality. On the other hand the black pearls from the pearl oyster of the Gulf of Mexico command high prices.

The constant recurrence in the newspapers of claims and counter-claims said to have arisen from the accidental finding of a pearl in an edible oyster or clam, shows how few are aware of the fact that the shelly concretions found at times in edible oysters of America and Europe are commonly rather objects of personal interest or of local curiosity, than of either artistic or commercial value. Indeed, it is doubtful whether the choicest pearl from such an oyster would sell for as high a price as $20. It is true that pearls of slight lustre have occurred in the hard clams of the Atlantic Coast. These are commonly of dark hue, though they may be whitish, pale lilac, brown, purplish or black. The white ones, resembling ivory buttons, have little value, but some of the dark pearls have sold at retail for from $10 to $100 each.

Evaluation of Pearls

Form.—According to form and appearance, pearls have been designated as follows: "paragons," large or exceptionally beautiful ones; "round," if perfectly spherical; "button," if domed on top with a flat or slightly convex back; "pear-shaped," when formed like a pear; "drop-shaped," if elongated, but larger at the lower end than in a true "pear-shaped" pearl; "egg-shaped," if of ovate form; "cone-shaped," if elongated but with one flat end; "top-shaped," if flattened at the top and with rounded sides; "seed pearls," those which are round or of irregular form and weigh a quarter grain or even less; "dust-pearls" designates those which are so small as to be almost valueless; "petal pearls," are rather flat, one end being often more pointed than the other; "hinge pearls" are those found near the hinge of the shell, and are further differentiated as "wing pearls" and "dog pearls," the former slightly resembling a wing, while the latter are pointed, elongated and narrower; "slugs" are irregular and distorted and often consist of an aggregation of imperfect pearls; "hammer pearls" have distinctly the form of a hammer; "baroque" designates pearls not having any of the typical form; "half-pearls" are usually made by cutting off the best hemispherical or rounded section of a pearl of irregular form, one such pearl not seldom furnishing three or four segments, each of which will be called a "half-pearl."

Calculation of Value.—As a general rule the method of estimating the worth of pearls is by establishing a base value for a gem weighing one pearl grain (50 milligrams) and then multiplying this amount by the square of the number of grains that any given pearl weighs. For example, if the base value is determined to be $10, then that would be the worth of a one-grain pearl, but a two-grain pearl would be worth four times as much ($2 \times 2 = 4$), or $40, while a ten-grain pearl would be worth $1,000 ($10 \times 10 = 100$). The origin of this system of valuation can be traced back to the sixteenth century, when Van Linschoten learned of it in India, and it must have been invented and elaborated many centuries earlier in that country. The base value of a pearl necklace can be determined in the following way: If the center pearl weighs 25 grains, multiply 25×25, the result being 625; then take the next two, three, or four pearls, as many as are of approximately the same weight, add their weights together, multiply the resulting figure by itself and divide the product by the number of pearls in the group. Carry out this system with the remaining pearls, grouping them according to their weights, finally, add all the quotients together, and divide the price of the entire necklace by this number to ascertain the multiple or base value.

Utilization in Jewelry.

Drilling.

As pearls come to us perfect from Nature's hand, they require no polishing or cutting as do precious stones. The most important operation in preparing them for use as ornaments is drilling, which is a very delicate proceeding. Formerly this was a laborious process, and even a skilful driller could not perforate more than from forty to fifty ordinary pearls in a day by means of a bow-drill operated by hand, but with one of the modern machines, 1,500 pearls of average size can be pierced in that time. The bow- or fiddle-drill is the favorite for piercing fine pearls. The arm of this is made either of steel or of wood, with a strong cord stretched across it in the style of an archer's bow. This drill is inserted in the end of a brass circular disk with a V-shaped groove on its edge, to admit of the string being passed entirely around it like a pulley, so that when the drill is in place and held at the other side, and the bow is moved up and down, the wheel with the drill rotates rapidly. Of late years drill-holes have been much reduced in diameter, in order to preserve as much as possible the weight of the gem which has become so costly.

When the pearl is not absolutely perfect, as is not very often the case, the poorest part or spot is chosen to form the beginning of the drill-hole.

Large pearls are put in a pair of calipers with a circular disk, one end of the caliper being placed on the spot to be pierced, the other end naturally touching exactly opposite. Each caliper end is rubbed with a little rouge or lampblack which leaves an indicating mark on the pearl. The drill end is then placed on the pearl, and the bow moved up and down, the work being so rapidly performed that five large pearls weighing fifteen grains can be drilled in less than an hour's time—of course with small pearls the operation is performed much more quickly.

Stringing.

In stringing pearls for a necklace, the thread, which is invariably of the finest quality of silk, is first passed through the metal eye, a pearl, or other object designated to serve as clasp; a knot is then made on it, and it is passed through the end pearl, after which another knot is made, and so on until all the pearls have been strung and the thread has been firmly secured in the opposite section of the clasp. Should there be a sufficient number of pearls for the designated length of the necklace, knots are only made at every third, fourth, or even fifth pearl. The silk thread must neither be dyed nor contain any chemicals. Its point is usually stiffened by an application of pure gum arabic dissolved in water. To avoid any danger of the thread becoming cut, the holes in the pearls are carefully reamed out until they become quite smooth. In the case of a long chain or sautoir, as many as three hundred pearls may be strung on a single row, and great skill is needed to accomplish the task properly. Necklaces require to be restrung, according to the frequency with which they are worn, every three, six or twelve months. If, when the thread is stretched it can be seen between the pearls, or at either end, this is an indication that they must be restrung.

In the case of a collar from thirteen to fourteen inches in length, there are frequently twenty-three rows of pearls, the rows being kept straight by four jeweled bars. Sometimes there are from ten to twenty-five pearls in a section between the bars, which means more than two thousand in a collar of small pearls.

Mounting.

Many of the pearls mounted in rings or as studs are set upon a peg. This is done to reveal the full size of the pearl, for if it is held in place by claws these must hide part of it. The use of a double peg is an element of safety, as it prevents the pearl from turning and thus become loosened and falling off the peg. The jeweler must exercise great care in mounting a pearl so that the settings may not scratch or mar it. Therefore, they should be carefully filed down: the file must not be allowed to pass over the pearl. It is also necessary for the wearer to prevent any sharp contact between pearls and hard precious stones which may be worn at the same time.

From 1840 to 1860 seed-pearl jewelry was much in vogue. It was generally sold in sets consisting of a collar, two bracelets, two earrings, a small brooch, and a large spray or corsage ornament. Sometimes a central pearl of from one to five grains, commonly a half-pearl, was made the central ornament. So favored was this type of jewelry that a seed-pearl set valued at $1,000 was shown in the Tiffany exhibit at the New York Crystal Palace in 1855. Mother-of-pearl constituted the background of these jewels, a layer of the material being cut to the required shape and then pierced whenever a pearl was to be attached; these were strung on with a special horsehair thread. Seed pearls in necklaces of from one to three strands have been extensively used since 1922. They have also been worked into quaint designs interwoven with jade, coral, onyx and other stones for bracelets, necklaces and other forms of jewelry.

PEARL ESSENCE.*

By HARDEN F. TAYLOR†

History of the Industry.

The first successful effort to imitate pearls closely was made by a rosary maker, Jaquin, in Paris, in 1656 (or 1680, the references are in disagreement). Jaquin found that the silvery material so common on the scales of fish, particularly the fresh water European fish, the "bleak" *Alburnus lucidus* (French, ablette; German, Ukelei, Laube), when applied to beads give them a lustre closely resembling that of pearls. The lustre is, of course, of widespread occurrence among the fishes, but that obtained from the ablette could be obtained with less contaminating impurities, and the fish was sufficiently plentiful to supply all the demand. About 40,000 fish were required to produce a kilogram of the "essence" or liquid suspending the lustrous particles, and the fish were not otherwise used. The method used for making the essence, according to Réaumur, was to pour the scales in a basin, agitate them with water, pour off the water, repeating this agitation in water several times to remove all the lustrous substances, mix the several quantities of water, allow the lustrous particles to settle for several hours, decant the excess of water; the remaining lustrous material is pearl essence. It was applied to beads of wax or alabaster. He used no preservative, and his beads were not waterproof. Later he used milky glass beads; and then hollow spheres coated inside.

Pearl making continued almost entirely a Parisian industry for a hundred and fifty years or so. Some pearls were made in Bohemia and in various cities of Germany and also in Japan.

Improvements were from time to time introduced. By the time of the American Revolution imitation pearls were being produced at the rate of 10,000 a day at a factory at St. Jean de Maizel. Among the more important improvements was the use of ammonia in the essence which serves to preserve it and assists in dissolving and removing some of the proteinaceous matter present. Wax was used to fill the hollow beads to impart weight and strength to the bead, and the art of making the hollow glass spheres was perfected. Finally the "indestructible" pearl was developed, marking the culmination of the imitation pearl industry as it is today—a solid opal glass bead, coated with the essence and protected with a waterproof lacquer, or made with a waterproof lacquer containing the pearly substances as a pigment.

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* Published by the permission of the Commissioner of Fisheries.

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Many researches during the past 200 years have been devoted to pearl essence and imitation pearls. At one time, a chemist "proved" the lustrous particles to be silver, then it was thought to be various earthy carbonates and phosphates, organic compounds containing lime; later it was reported to be a compound of guanin and lime. Finally, Bethe (1895) proved it to be pure crystalline guanin. It has all the properties of guanin.

With the outbreak of the great war the European industry was demoralized, and a demand sprang up for an American source of pearl essence. There are, of course, many species of fish in this country whose skin is silvery with guanin crystals, yet difficulties were encountered in using them because of the presence in the skin of other dark pigments. These difficulties were soon overcome, and the essence is now being made from herring, alewives, shad, and numerous other fishes constitute a great potential source of the material. The writer has made good quality essence from gizzard shad, silver carp, menhaden and other species. The California sardine is a great potential source of the material so that, as far as raw material is concerned, the business can be expanded almost indefinitely. Numerous concerns are making the essence, a great many are making pearls, and some essence is exported to the European trade. Many pearl manufacturers make their own essence; some is made by essence makers and sold in 3 or 4 ounce bottles, containing lustrous particles, which, when settled out of suspension, occupy about 5 cc.

Composition and Preparation of Pearl Essence.

The lustrous substance is a deposit of thin blade-like crystals of pure guanin in the epidermis of fish. When this epidermis is scrubbed off of fish scales, under water, it is partially disintegrated and the lustrous particles are suspended, making a glistening suspension. The crude liquor so obtained is filtered through cheesecloth or bolting cloth, and allowed to settle. The excess water is decanted off and fresh water is poured in, and the whole again allowed to settle, and is decanted. Strong ammonia is now added, and the whole set aside some time to digest the proteinaceous matter. The concentrated liquid is pearl essence, or essence d'Orient, and if it contains enough ammonia will keep well. Glass or rubber stoppered bottles should be used, as cork is attacked by ammonia and discolors the essence. Salicylic acid is used to some extent as a preservative for the scales while they await treatment. By other improved methods the lustrous material is suspended in acetone, amyl acetate, etc., which are solvents of the nitrocellulose lacquer. Different grades are made, distinction being made in freedom from color, and in fineness of grain. If gray or otherwise off color, the essence is not regarded as first class. Also, it is important that the particles be small. The crystals are roughly proportionate to the size of the fish—those coming from small herring and alewife being smaller, for example, than those from the shad, and making a fine grain essence of high quality. The essence made from shad scales is, without refinement, perhaps too coarse to make first quality pearls. The crystals are, however, not of uniform size; the large ones may be separated from the smaller by levigation, or fractional sedimentation, the larger crystals sinking to the bottom of a container faster than the smaller ones. This process may be carried out by causing the essence to run through a large horizontal glass tube, or through a large U-tube, regulating the rate of flow so that in passing through the larger crystals have time to settle out, but the smaller ones do not. The sediment in the tube is again run through to remove the fine particles. Similar results may be obtained by sedimentation in bottles, the time allowed being regulated to affect the degree of separation desired. By this process of levigation, essence of good quality can be made from shad scales; and while there is a considerable loss in particles too large to use, the larger quantity available from shad scales makes up for the loss. No doubt these larger particles could be ground to make them suitable, but so far this grinding does not seem to have been resorted to.

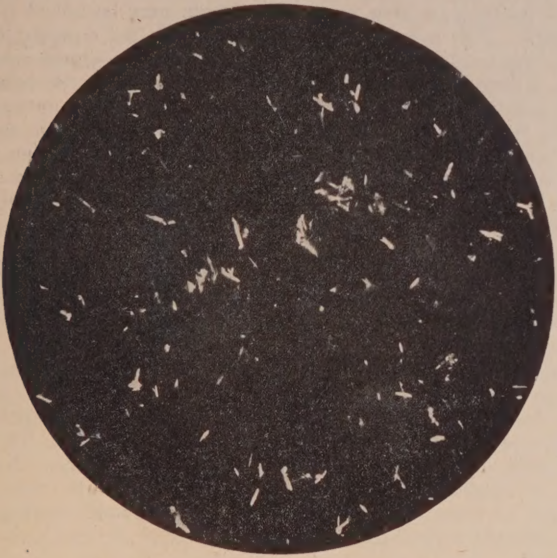

FIG. 52.—Pearl essence, highly magnified, showing guanin crystals.

Good quality of pearl essence is of brilliant lustre and when slightly agitated gives a unique and most beautiful "whirly" effect. The color may be silvery white; some high quality specimens are faintly pinkish. Grayish or brownish colors detract from the value of the essence.

Because of the usual presence of some protein in pearl essence, protein coagulants are incompatible with it. Alcohol, heat, formaldehyde or other preservatives must be avoided. The lustrous crystals are soluble in hydrochloric, nitric or sulphuric acid, and in caustic soda, or potash solutions.

They are not dissolved by ammonia, acetic acid, acetic anhydride, organic acids generally, or any neutral organic solvent. They are flocculated from solution by electrolytes or other flocculating agents. The protein usually present holds them dispersed and makes them shine. If absolutely pure crystals are shaken up in distilled water they do not shine strongly, but when a small amount of egg albumen and ammonia are added, they become lustrous.

In making wax filled beads, the essence is allowed to settle, the ammonia water is decanted off, and pure gelatin or fish glue is put in with pure water, so that a very strong gelatin solution is made, and is preserved with clove oil or tricresol; a little eosin or safranin may be added if a "flesh" tint is desired. This is liquefied by heat and while hot injected with a fine pipette into the bead which is being revolved on a toothpick spindle. As the gelatin spreads over the inside of the bead, it may be caused to set quickly by touching the outside of the bead with a brush moistened with ether. The rapid evaporation of the ether chills the gelatin and sets it. The bead may be laid aside in a dry atmosphere to dry. When the beads are dry inside they are filled with wax—equal parts of paraffin and Japan wax being a suitable combination. Often barium sulphate, 20 parts, is added to 80 parts of the wax to impart weight and whiteness. For the hollow glass beads, the cheaper grades are blown in molds from tubing, and then cut apart. The finer grades are blown individually, of a specially prepared soft, colorless glass. An iridescence (more or less unnatural in appearance) is sometimes produced by treating the beads cautiously with a solution of hydrofluoric acid.

The "indestructible" pearls are made in several different ways, the details of most of the processes being trade secrets. One way is to coat the solid glass bead (which must be of milk or opal glass) first with the ordinary pearl essence containing some gelatine, or fish glue, by means of dipping or with an air brush, and this coat is allowed to dry. A protecting lacquer of nitrocellulose or pyroxylin in amyl acetate or other solvent is then applied to make the coating waterproof. These coatings may be applied alternately several times, and the finish polished with chamois skin and fine chalk.

Another method consists of making an emulsion of the pearl essence with the nitrocellulose solution and applying the emulsion. Some manufacturers have a process of incorporating the lustrous material directly into amyl acetate, in which the pyroxylin may be dissolved directly, making a lacquer that is applied to the bead. When these solvents are used, the lacquers may be tinted for "oriental," "flesh" or other tints by the addition of small quantities of dyes. When the inside surfaces of hollow beads are coated with the gelatin or fish glue lacquer, a little eosin or safranin imparts a delicate pink or "flesh" hue.

The difficulties introduced by using non-aqueous solvents have been overcome by some manufacturers by using a cupra-ammonium solution of cellulose (cotton) in which the aqueous pearl essence is stirred directly. The bead is coated with this mixture and the copper is later removed.

The beads for "indestructible" pearls are, as stated, solid, and of opal or milk glass. The stock used is tubing with the hole of suitable size for the hole through the bead. Appropriate lengths are cut off and moved around in a refractory material, like fire clay or graphite, which plugs the holes. The pieces are then introduced into a revolving iron drum, containing powdered talc. The drum is heated to the softening point of the glass, but not so as to cause the beads to stick or flow. The talc prevents sticking. The drum is revolved till the beads are all shaped, and continued until they are cool.

A method of preparing pearl lacquer, based upon an entirely different principle from the foregoing processes, has been devised by the writer of this section.[10] It has been pointed out that among the greatest difficulties of preparing pearl essence is that of removing the excess proteinaceous matter. Strong ammonia, or acetic acid, hydrolyzes and partly removes it, but not to such an extent that the guanin particles can be introduced into non-aqueous lac solvents without coagulation and precipitation. The ability to incorporate the lustrous guanin particles into lac solvents, such as amyl or ethyl acetate is, of course, highly desirable. The following procedure is followed to accomplish this result:

The scales (they need not be clean) are washed free of adhering lustrous matter, the water containing the latter being drained off. This suspension in water is allowed to subside, and the supernatant water, containing any blood, is decanted off. The remaining thick fluid, containing the lustrous particles of guanin, is treated with a digestion mixture of pepsin, 2½ gm., and acetic acid (glacial), 30 cc. to each liter of fluid, and allowed to act 48 hours. This mixture completely digests and removes all proteinaceous matter from the guanin crystals. Hydrochloric or other mineral acids cannot be used to activate the pepsin, because these readily dissolve the guanin crystals, while acetic acid does not.

After 48 hours' digestion in the pepsin-acetic acid mixture, the surfaces of the guanin crystals are clean, and they now possess the peculiar property of being more readily wetted by ether and certain other non-aqueous liquids than by water. Advantage is taken of this property to separate them from the fluid mass, as follows: Into the vessel containing the digestion mixture and the guanin crystals, ether is poured, standing as a separate layer on top. The vessel is gently rocked. The lustrous crystals of guanin, being more readily wetted by the ether, leave the water and pass into the ether layer, leaving all dirt, organic matter, and the like in the water. Fatty substances also pass into the ether, but the crystals are allowed to settle out, the oily ether decanted and replaced by clean ether. The ether (which should now be strictly anhydrous, as by treatment with calcium carbide) is replaced once or twice, removing all the oil or fat. The lustrous material is now clean, brilliant, and can be kept indefinitely in ether, or easily transferred to ethyl or amyl acetate. High grade nitrocellulose (celloidin or parlodion) is dissolved in the ethyl or amyl acetate forming a pearl lacquer which is applied directly to the bead. Ethyl acetate is preferable because it evaporates more quickly.

Large quantities of pearl "essence" or lacquer can be readily produced by this process. No elaborate apparatus (except ether still for recovering ether) is needed. Ordinary scales as they come from the market are satisfactory, and surprisingly large quantities of the lustrous material are produced from the scales.

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[10] Unpublished at the time of writing this chapter, but to be published elsewhere, in detail.

The hues, such as "oriental" or "flesh" can readily be produced by the tinting of the lacquer with appropriate dyes, like sudan III or eosin.

The process as described is not patented.

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Chapter 9.

Mother-of-Pearl and Blister Pearls of Marine Origin.

By GEORGE FREDERICK KUNZ[*]

THE beautiful lustre of mother-of-pearl not only appeals to the most refined artistic taste, but has been, and still is in high favor among semi-savage peoples. Among the Dyaks of Borneo, many of the warriors wear a large polished pearl-shell attached as a pendant to the corselet, or else inserted in the shield. A like usage is noted in Polynesia, and there is in the British Museum a very elaborate corselet, studded with mother-of-pearl shells and having as additional adornment a deep fringe of tiny pieces of pearl shell carefully strung together.

Formerly the North American Indians wore necklaces of shell beads made from clam, abalone or fresh water mussel shells. These beads also served as a medium of exchange in lieu of money.

To-day the mother-of-pearl is widely used for decorative purposes. It is impossible to estimate accurately the world's production of pearl objects but it is probably in the neighborhood of $100,000,000.

Practically the only marine mother-of-pearl shells produced in the United States are those taken in the abalone fishery of southern California and in the scallop fishery of the Atlantic Coast. However, about two million dollars' worth of marine pearl shells are imported into this country.

France imports large quantities of shells for her button and jewelry trade. The latest statistics regarding the annual importation of pearly shell into France have been given as follows:[†]

Trochus Shells	Long Tons
New Caledonia and Hebrides	600
Macassar (all Dutch East Indies, etc.)	1200
Fiji Islands, approximately	300
Philippine Islands, approximately	150
Jibuti (all of Red Sea)	1200
Total	3450
Lingah Shells	
Venezuela	from 800 to 1000
Bahrein (Persian Gulf)	2000
Total	3000

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[*] Vice-President of Tiffany and Company, New York City; President, New York Mineralogical Club.

[†] Communicated by Mr. Ludwig Stross of New York and also by Paul Rie & Cie of Paris, who have contributed much valuable information.

Great Britain carries on a considerable traffic in shells, which is especially important in the commerce and industry of many of the outlying divisions of the Empire. Australia is the largest contributor to the British shell market. Statistics[1] giving the imports of shells into the United Kingdom for the years 1913, 1915, and 1919 are given in Table 27.

TABLE 27

IMPORTS OF SHELLS INTO THE UNITED KINGDOM

Country of Origin	1913	1915	1919
Germany	£ 23,444	......	......
Dutch possessions in the Indian Seas	73,152	6,273	......
France	12,862	4,124	4,818
French possessions in the Pacific	91,995	17,446	......
Italy	6,174	1,173	11,372
Japan	12,175	958	14,804
Persia	3,173	4,414	......
United States	16,374	5,179	115,089
Philippine Islands and Guam	11,345	3,030	6,060
Mexico	55	......	......
Colombia	2,135	116	......
Panama	5,581	376	12,806
Other foreign countries	20,662	20,505	18,315
Total from foreign countries	279,127	63,594	183,264
Egypt	11,202	1,895	15,519
Zanzibar and Pemba	2,547	816	645
Aden and dependencies	19,596	12,106	6,882
British India	48,877	21,585	52,680
Straits Settlements and dependencies	59,395	79,509	63,833
Ceylon and dependencies	3,918	141	135
Australia	368,969	166,165	209,824
Territory of Papua	14,142	1,329	......
New Zealand	3,440	40	8,196
Bahamas	3,470	370	1,023
British West Indies	6,075	1,685	20,084
British Honduras	4,485	209	1,844
Other British possessions	5,580	1,667	28,462
Total from British possessions	551,696	287,517	409,127
Total Imports	830,823	351,111	592,391

Structure and Composition.

Structure.—The shell of the pearl oyster is formed of three main layers, the outermost being designated the periostracum. Within this is the "prismatic layer," which is thicker than the outermost layer, and is constituted by an aggregation of calcareous columns or prisms, disposed at right-angles to the periostracum. In this, as in other parts of the shell, there is a combination of organic and inorganic substances, the organic part, termed conchiolin, a nitrogenous substance similar to keratin, forming a kind of network for the deposition of the carbonate of lime. Within both these layers lies the most important one, the nacreous layer, consisting of mother-of-pearl. This layer is secreted by the external surface of the mantle of the oyster, and may continue to increase in thickness during the animal's existence. Its structure is composed of a series of exceedingly thin plates, overlapping one another, and arranged parallel to the shell's surface. The edges of these thin plates, or laminæ, are of zigzag form, and since the mother-of-pearl surface shows both faces and edges of the laminæ, this irregular surface, through the phenomenon of light interference, displays the wonderful, and so greatly admired iridescence designated as nacre.

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[1] Bureau Foreign Domestic Commerce, *Commerce Repts., 4* (1921), 310-1.

Pfund[2] determined the thickness of the laminæ for many different samples of mother-of-pearl from a fresh water mussel (*Obovaria ellipsis*) (Lea) to lie between the limits of 0.4μ and 0.6μ.

Clement and Riviere[3, 4] have studied the deposition of calcium carbonate in an albuminous medium and have been able to imitate nature and obtain the deposition in the form of a diffraction grating of a physical structure resembling mother-of-pearl which possesses the same property of iridescence.

The Mother-of-Pearl Fisheries.*

Species of Mollusks Utilized.

The principal genera of mollusks utilized commercially for the manufacture of mother-of-pearl objects are *Margaritifera* (Jameson) or *Meleagrina, Gasteropoda* and *Haliotis.* Certain species of the genera *Pinna, Malleus, Trigonia,* and *Nautilus* are also taken but these mollusks are of lesser commercial importance.

Margaritifera maxima Jameson, the large white mother-of-pearl shell of Australian Papuan and Malayan waters, commercially called "silver-lip," "gold-lip," etc., *M. margaritifera,* the "Bombay," "Tahiti," "Gambier," "Aukland," "Panama" shell, etc., and *M. vulgaris* Jameson are the species of *Margaritifera* or pearl oyster of the greatest commercial importance.

Haliotis splendens, H. iris and *H. midæ* are the species of abalone which are utilized to the greatest extent.

The species *Turbo olearius* or *marmoratus* and *Trochus dilatatus* (*niloticus*) of the genus *Gasteropoda* are of more commercial value than other species of that genus.

Geographical Distribution of Mother-of-Pearl Shell Fisheries.

Pearl Oysters.

Margaritifera vulgaris Jameson.

A small species of shell which grows only to about the size of a silver dollar. The color is generally dirty white or yellowish. The weight ranges from eight to fifty shells to the pound.

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* The author's thanks are due Dr. Roy Waldo Miner, Curator of Conchology, American Museum of Natural History, for assistance in the revision of the manuscript.

[2] *J. Frank. Inst., 183* (1917), 453-464.

[3] *Compt. rend., 174* (1922), 1353-6.

[4] *Chimie et industrie, 8* (1922), 872-4.

They contain pearls of fine lustre, pearls weighing 23 and 37 grains having been taken out of specimens from Sharks Bay, Australia.

These shells are used in the manufacture of very cheap shirt buttons only. Very often when market conditions are bad, or when freights are high, it is not profitable to ship these shells as the proceeds would not cover the freight. In this case they are dumped in enormous piles on the beach and deteriorate under the hot sun, becoming brownish and chalky (blinde), so that when touched they leave a white chalk dust on the fingers. Often, however, after years of exposure, they are dug out from the sand. As many as several tons of these shells, buried for years in Sharks Bay, have been thus dug out and shipped to Europe. They are not used industrially in America.

Ceylon.—At the present time the pearl fisheries here are ruined and produce next to nothing. Although it is one of the world's oldest fisheries it is now practically unworked. Some nine years ago the Commissioner of Ceylon fisheries stated that sea currents had developed in the Gulf of Manaar, and that the shell beds had been covered with sand.

Lingah—Persian Gulf.—There is a very extensive fishery near Bahrein, where great quantities of pearls are obtained. Lately the shells have not been coming to Europe.

In the trade, all the *Margaritifera vulgaris* are called "Lingahs." Hence we read of "Ceylon Lingahs," or "Venezuela Lingahs."

West Australia, Sharks Bay.—The fishing here has been carried on for about sixty years. Formerly it was very productive, but it has been "over-fished," and is now very slowly recovering. At present it produces perhaps 200 tons per annum. There is no fishing south of Sharks Bay.

Venezuela (Porlamar).—Here only very inferior small shells are fished, almost exclusively for the contained pearls. The shells are often full of veins and are very thin. Only at times can they be used industrially. Probably these oysters are of a different species.

Belbil.—In the southern part of the Red Sea, *Margaritifera vulgaris* are found alongside of the regular shell, but only in very small quantities, and mostly not worth the freight charges.

Margaritifera (Various Species)—White Shells.

Sydneys.—These are also termed "Queensland" or Thursday Island shells, when they are fished in this island. They are large white shells, weighing up to one pound each. There is a great fishery here.

Port Darwin.—This is a small fishery in the northern part of South Australia, from which the finest white shell has been secured. At present this fishery is almost abandoned.

West Australia.—These are also called "Fremantle" by the English trade, as Fremantle was formerly the most important port of shipment for white shells. In 1922 the output was 1,040 tons, at about £160 to £170 per ton. This white shell is not as large nor as fully developed as the "Sydneys" or "Aroes." They weigh up to about one pound each.

Aroes.—These are also called Macassars from the former shipping port; now they are mostly shipped direct from Dobo. There are two kinds, practically of the same quality, but those called "native fished" have been recovered by native fishers who plunge naked into the water. The deep-water fishing with scaphanders produces many old and therefore defective shells which are worm-eaten.

The mother-of-pearl furnished by the Netherlands East Indies has been regarded as some of the best in the world. The chief fisheries are those of the Aroe Islands, near the southwest coast of New Guinea. As is commonly the case with native industries, the methods employed are very primitive. The work is principally done in the season from February to April. The Chinese compete actively in the purchase of the mother-of-pearl, and thus good prices are obtained. In 1906 the fisheries were leased to the Celebes Trading Company for 85,000 florins a year (about $32,000), the natives being indemnified by an annual grant of 25,000 florins ($10,000). In 1914 the Celebes Company employed over 1,500 men and had a fleet of 150 luggers, but the industry was much hurt by the war. In 1918 the fleet was acquired by Schmid and Jaendel, of Macassar, this firm having secured a contract for the fishing rights until 1924.

America is by far the most important market for all the above white shells, the best coming to the United States, with comparatively very few exceptions, which go to England for knife handles, etc., only the very poorest kinds of defective shells are taken to central Europe for small buttons.

Yellow Shells.

Yellow shells, curiously enough, are only found within a belt which is close to that inhabited by the yellow races. They are found from Lower Burma, along the Malay Peninsula and Sumatra, and also in the numberless islands of the Dutch East Indian Archipelago, the area ending abruptly in the southern part of the Philippine Islands.

These shells often grow to enormous size, weighing exceptionally as much as from two to three pounds apiece. The center is often perfectly white, while the lips and the part close to the bark is often dark yellow or almost brown.

By cutting a cylinder out of any of these shells, the top layers can be often used for white work, while the lower parts are utilized for inferior purposes.

Singapore.—A mixture of all sorts of yellow shells coming from various islands where they are fished, such as Bangay, Bima, Batjan, Solor, etc., etc., and formerly derived to a great extent from shipments from the Philippines, where the Chinese merchants of Singapore have their Chinese correspondents all over, both beach-combers and traders. The various qualities are made into uniform mixed lots by the very astute and unscrupulous Chinamen.

Manila—Zamboanga, or Sulu.—These are fished in Mindanao (Zamboanga) and the Sulu Archipelago and are generally denominated "Manila Shells."

New Guinea, or Moresby Shell (Port Moresby).—An inferior yellow shell, often almost copper-colored. An unimportant fishery.

Mergui.—From Mergui, Lower Burma. These are the best of the yellow shells. They are very thick and are whiter than most of the yellow shells. The monopoly of shell (not snail) fishing is yearly leased by the British Government to local merchants.

Green Shells.

While the expressions "white," or "yellow," or "black" shells are generally used in the trade, the denomination "green shell" is not in general use. It seems to designate shells of inferior grade, of a dirty, greenish-white color, and usually of much smaller size than the white and yellow shells.

Red Sea.—These are called Egyptians because they were formerly shipped to Europe via Egypt (Cairo). This trade has long ceased, and all these shells go directly from their original port, via Suez, to destination.

The Red Sea shell is brought into the ports of Jeddah, Suakim, Massowah, and Aden. Suakim was never important and of late years Jeddah has lost most of its importance on account of misgovernment and political troubles.

While fishing is carried on in many parts of the Red Sea, the great fishing grounds are the two island groups of Dahlak and Farsan. Massowah, in the Italian Eritrea, is now the principal port of export. Most of the "Egyptian" shells go to Austria and Bohemia, where there is an old-established industry.

Zanzibar.—These shells are inferior to "Egyptians," being smaller and copper-colored.

Mussels.—A highly inferior kind of greenish shell fished in quantities in the Persian Gulf, alongside the "Lingahs." They are thin, with enormous black lips, something like the razor-shell. In Austria they have been, and perhaps still are used for cheap buttons, the local Austrian name being "Ohrnaschel" or earlobe.

Panamas.—These are, generally speaking, smaller than the "Egyptians" and of inferior grade. Outside the Venezuela Lingahs they are the only known American shells. They are of a dirty-white line, and are often very thick. According to origin these are the Panama shells proper, fished within a short distance of the town of Panama.

Costa Rica.—A shell of rather better quality, more yellow than green, but very often worm-eaten and having bad holes, which spoil the shell.

Lapar—Acapulco—Mazatlan.—Three grades of shells coming from Lower California and Mexico. They are similar to "Panamas" in size and general aspect, but are dark-edged.

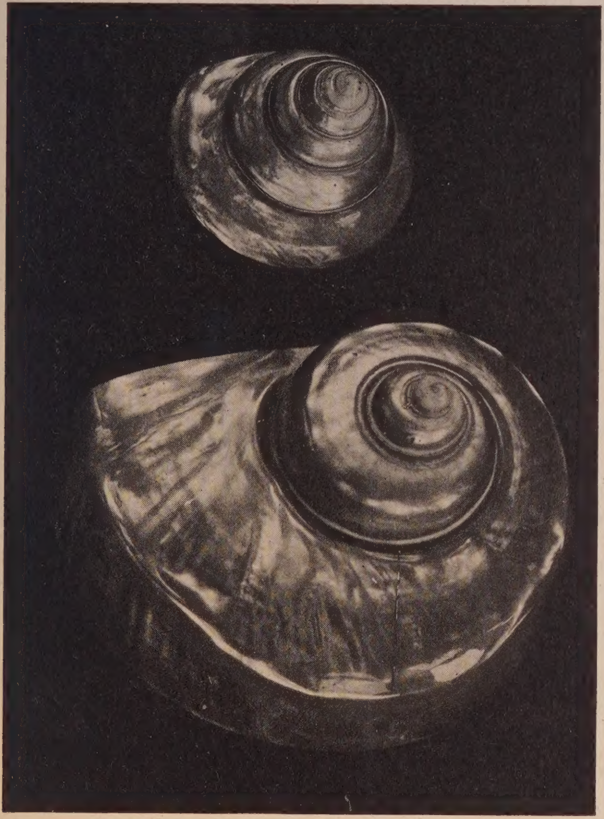
Black Shells.

These are used for fancy buttons, mostly for cloaks. The industrial use suffers from the employment of dyed buttons, made of inferior grades of shell, but dyed so as to look like the genuine shell. The chief origin of the black shells is the Pomota group of islands, where the French Government has each year opened a fishery. The shells are generally called "Tahitis," but represent many different qualities, according to the special fishery. "Hikueru" is generally considered the best; other origins are the

Raiatea and Fukarara. The output of the 1922 fishery is put at 1,400 tons.

Gambier.—These islands produce an inferior black shell, poorer than the above in color and shape.

Fiji.—Produces a poor class of black shell.



Courtesy American Museum of Natural History, New York.

FIG. 53.—*Turbo marmoratus,* with external surface removed to show pearly blister.

Green Snails *(Turbo marmoratus).*

These are used for buckles, buttons, inlaid work, etc. They are taken in Penang, Singapore, Mergui, Australia, New Guinea. The Penang and Singapore snails are considered the best, those from Australia and New Guinea the worst, since they are harder and have a peculiar thick ring around the bottom, which cannot be utilized industrially. Very fine inlaid work is done with this material in furniture in Tonquin, for which some snails are used.

Trochus.

France has been the only country to work Trochus in steadily increasing quantities, up to thousands of tons. At the outset most of them came from Singapore, that is to say, from the neighboring islands, but later on Trochus began to be fished all over the world, and to-day the Red Sea fisheries (Jibuti, Massowah) produce 1,000 to 1,500 tons.

The Fiji Islands, New Caledonia and Australia are producing Trochus of various qualities for industrial purposes in enormous quantity.

So far only small quantities have been brought to the United States, where they have been disliked because they are difficult to handle and to work. For a time France enjoyed a practical monopoly, but recently Japan has taken up this industry, and to a good extent driven out France. For many years enormous quantities of Trochus buttons have been imported into the United States from France and Japan, more especially under the old tariff. Whether the higher duties now levied on them will result in fostering a use of this material here is regarded as an open question.

Haliotis—Abalones.

These exhibit a splendid range of colors. They have been used for inlaid work (opera-glass cases, etc.) and also for buttons. In Japan they are known as Awabi, or "ear shells," this being also the meaning of the scientific name. They constitute but an unimportant article of commerce in Japan.

Green Ears—Red Ears—Blue Backs.—These are not very important commercially. They originate in California and Lower California. The "red ears" are almost worthless; the "blue backs" make a cheap button, and the "green ears" are adapted for fancy work, as the color is very vivid, and also for inlays. An inferior kind of "green ear" comes from New Zealand.

Fishery Methods.

The pearl, mother-of-pearl, and blister pearl fisheries are in reality but one fishery, for the shells of mollusks yielding pearls are nearly always utilized for their mother-of-pearl. On the other hand in many fisheries, as in Australian pearl shell fisheries, mother-of-pearl is the chief product, pearls being obtained as a valuable by-product.

The methods employed in the taking of pearl shells are, of course, the same as those of the pearl fisheries, viz. naked diving, scaphander diving and dredging. Since these have been described in the preceding chapter (page 151), and since it is obviously impracticable to discuss the details of these methods as employed in the various shell fisheries, these points will not be considered in this section.

Australian Pearl Fisheries.

The Australian pearl fisheries are the most important in the world for the production of mother-of-pearl. They have been in active operation since 1868, especially on the northwestern coast of Australia from Cape York to the Northwest Cape, a distance of 2,000 miles. To these fisheries must be added those of Torres Straits and Queensland in the northwestern part of the great Australian continent. The chief revenue is derived from the pearl shells, although a certain number of pearls found within the shells become the property of the captain of the fishing craft. The peak of the Australian pearl and pearl shell production was attained in 1912, when pearls valued at £106,375 were reported, and 2,103 tons of pearl shell, with a value of £530,298, were produced. Of this 1,596 tons came from the waters of West Australia.

The pearl shell grounds of Queensland, Australia, extend from Thursday Island, northward, almost to the shores of New Guinea, thence to the westward of Booby Island and to the eastward of Bramble Bay, thence southward to Cooktown. For many years the center of the fishery has been Thursday Island, whence the fishing fleets set out for their cruises and whither they return with their catch, the great bulk of the shell being shipped for export from this island. The first discovery of pearl shell in Queensland waters was made in the year 1868, by a Captain Banner of Sydney. The pearl shell found there is the *Margaritifera maxima* Jameson, locally called "gold edge" and "silver-lip." A smaller variety, locally termed "black-lip," is the *Margaritifera margaritifera.*

The total quantity of pearl-shell and Trochus shell, the value of the product and the number of vessels engaged in the Queensland fishery from 1912 to 1921, were as follows:[5]

TABLE 28

PRODUCTS OF THE QUEENSLAND SHELL FISHERIES

Year	Pearl Shell, Tons	Value, Pounds Sterling	Trochus Shell, Tons	Value, Pounds Sterling	Number of Vessels Engaged
1912	464	92,733	36	637	170
1913	468	110,208	41	735	180
1914	311	63,506	34	714	182
1915	84	15,132	115	2,550	137
1916	107	2,484	1,048	23,499	124
1917	189	28,111	933	25,610	126
1918	268	42,204	611	24,116	138
1919	309	55,143	598	35,594	155
1920	388	73,348	568	51,020	160
1921	328	53,987	295	21,942	112

In the Queensland fisheries, no shell measuring less than 5 inches across the nacreous surface is permitted to be exported, and all shells are inspected by a government official before exportation. The pearl fishery

[5] These data have been courteously communicated by G. L. Beal, Under Secretary of the Queensland Treasury, under date of May 29, 1922.

is conducted solely for the raising of mother-of-pearl shell, not for the beautiful gems the shells sometimes contain, and it is remarkable that in spite of the large quantity of shells recovered fewer pearls occur in the Queensland shells than in those from other fisheries. Although the statement has been made that in one year the value of these gems amounted to £70,000, there is no official proof of this figure.[5]

Society Islands.

The mother-of-pearl shell exported from Tahiti, Society Islands, to the United States during the first six months of 1922, had a value of $83,611 at normal exchange, four times as much as the value of the exports last year. The resources of the beds give no indication of approaching exhaustion, and the fishing is carefully safeguarded by the colonial governments. As a rule, the native divers and shell-fishers have to be refitted each season. The low price of pearl shell operates to retard extensive exploitation. Consul Withez states that it is not possible to give a current local price for the pearl shell, but that the last New York quotation known to him was 10 cents a pound. There is an export tax of 120 francs per metric ton, plus 60 francs per ton, as a so-called "loading charge," and also an ad valorem export duty of 2.20 per cent. The output has been strictly limited to prevent the fishing of immature shells.

Philippine Pearl Shell Fisheries.

While exact data regarding the output of the Philippine pearl shell banks are not available, it has been estimated that the annual yield of "gold-lip" pearl shells is probably between 300 and 400 tons, valued at from $175,000 to $200,000. A certain number of these shells are exported unworked, the remainder being made into buttons and other objects in workshops at Manila. The value of the annual pearl yield is placed at a considerably higher value, as high as $500,000, the proportion of pearls being larger than in the case of the Australian or Celebes fisheries.[6]

Trochus Shell Fisheries.

In regard to the production of Trochus shells in New Caledonia, this island, with the neighboring New Hebrides, supplied France with as much as 2,000 tons in the years 1911 to 1914. As, however, during the war the natives had all the work they needed in the chrome and nickel mines the fishing was neglected, but after the slump in nickel set in, fishing was resumed, and the annual returns for 1919, 1920 and 1921 have ranged from a minimum of 500 tons to a maximum of 700 tons.

The Macassar fisheries, comprising the whole of the Dutch East Indian possessions, ceased to be a source of supply for France, because prices mounted too rapidly, but Japan was able and willing to buy up all the product. It is estimated that prior to the war these fisheries produced about 1,200 tons annually and it does not seem likely that the output has decreased. An entirely new field opened up during the war, and exclusively worked by Japan, was the fishery off the Queensland coast of

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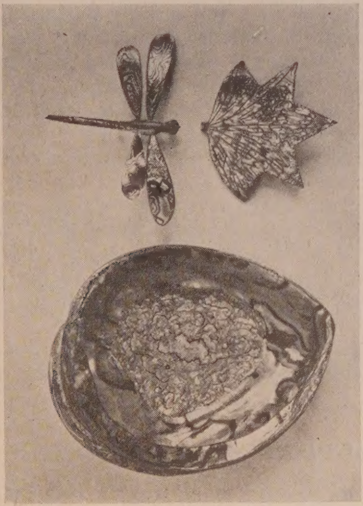
[6] Boomer, J. F., *Commerce Repts., 4* (1917), 1140-7.

Australia. Here the work was done by Japanese and the product was shipped immediately from the fishing grounds to Japan. Recently, because of the slump, the work here has ceased.

In the Fiji Islands, shell fishing has been carried on spasmodically, and the product appeared in London in September, 1921, but the sales were at such a very low figure that further shipments were discouraged, the shippers having to bear a considerable loss.

Of Lingah shells the production of Porlamar, Venezuela, has obtained an annual maximum of about 1,000 tons. In 1921, the fishing was suspended, but in the year 1922 it was resumed. The returns from pearls are much less than from the shells. A maximum output of some 1,200 tons is regarded as possible, but it is estimated that the fishing season of 1922 scarcely yielded more than 600 tons.



Courtesy American Museum of Natural History, New York.

FIG. 54.—*Haliotis fulgens.* California ornamental objects made from *Haliotis* shells.

The Persian Gulf fisheries have been most unfavorably affected by poor communications and high freights, so that but little has been shipped of late. It is believed that before the war, as much as 2,000 tons of mussels and Lingahs were recovered annually, but although the fishing was not abandoned, the output was left on the beach to perish. On the other hand the Ceylon fishery has quite died out.

The California Abalone Fishery.

The abalones (*Haliotidæ*) of the California coast have been eagerly sought for by pearl fishers, because of the beauty of their nacreous covering and its great brilliancy. As the zoological name indicates, these shells resemble in general outline the form of the human ear; they are also distinguished by their flatly spiral, bowl-like form.

The most important abalone fisheries in California are located at Santa Catalina and San Clemente Islands. The mollusks are gathered by divers, chiefly Japanese and Chinese, dressed in scaphanders.

In fishing, the boat containing a crew of one diver and six assistants is either rowed or driven by motor to the fishing grounds. When over the right bottom, the diver gets into his suit which is adjusted by the assistants. On the bottom the diver detaches the abalones by pushing a chisel under the expanded foot and quickly prying it loose. As soon as a diver secures a net full of abalones, the signal is given, and the mollusks are hoisted aboard. The net is usually filled in about six minutes with some 50 green and corrugated abalones. During his shift on the bottom, the diver gathers from 30 to 40 basketfuls, each containing about 100 pounds of abalones, or altogether 1½ to 2 tons.

A few naked divers work in water up to 20 feet in depth, but it requires six men to take as many abalones as one man in a scaphander.

Black, red and green shells are obtained. In polishing these shells, they are ground first on a carborundum wheel until the desired colors are reached. The desired surface is obtained by polishing further by a felt wheel sprinkled with carborundum dust glued to the wheel. Finally it is polished with a wheel made of many layers of cotton on the edges of which tripoli has been rubbed.

A single shell yields as many as 15 pieces of mother-of-pearl suitable for ornaments. Scimitar-shaped paper knives are often cut from the shells.

Japanese Mother-of-Pearl.

Although the pearl fisheries of Japan are not extensive, except in a few localities, the aggregate yield has been considerable. The awabi, or ear-shell (*Haliotis gigantea*) which is found on the coast of Japan, Korea, etc., furnished many pearl forms, although this species is much smaller than the California abalones. Its smooth, nacreous surface is unfortunately lessened in value by the size of the marginal perforations. Its opalescent tints adapt it well for the manufacture of certain types of buttons and buckles, but it is chiefly used for inlays or for marquetry work, its fine texture and beautiful coloring recommending it highly for these purposes.

The Chank Fishery of India.

About 2,500,000 chank shells are taken annually in India where that mollusk (*Turbinella pyrum*, Linn.) is considered sacred by the Hindus. The chief fisheries are located at Tinnevelly, Ramnad, Travancore, Kathiawar, Ceylon, and along the Carnatic coast. The shells are taken principally by native divers although some in shallow water are taken by means of hooks. This fishery is ancient, dating back more than two thousand years.

The chank shells are manufactured into bangles and other ornaments for Indian trade.

Classification of Shells.

The various kinds of pearl oyster shells have been thus classified in the English market according to their size and quality:

1. Bold (large size)
2. Medium
3. Large medium size
4. Small medium size
5. Chicken (bark)
6. Dead (dead bark)
7. Pieces
8. Broken
9. Pickings

Certain special designations refer to the source, as for example:

"Ceylon" indicates shells of the *Margaritifera vulgaris* Jameson fished in the Gulf of Manaar, near the Island of Ceylon. These shells are brilliant and do not exceed nine centimeters in length; they are thin, and the valves are prolonged into posterior wings at the hinge. The nacreous stratum is very thin.

"Mergui" refers to shells of the *Margaritifera,* fished in the Burmese Archipelago of Mergui. Here are also secured shells of the *Turbo marmoratus* which are green and are therefore denominated green-snail-mergui.

"Sulu" (Jolo). Shells fished in the Archipelago of Sulu; as they are yellowish on the edges, they are denominated white yellow-edged shells. They measure from 18 to 25 centimeters and have a thick and lustrous stratum of nacre, which is white with yellowish reflections.

By color, pearl shells may be divided approximately as follows:

White Shells—West Australia, Port Darwin, Macassar.

Yellow Shells—Manila (Sulu), Mergui, Bina, Singapore. This last named class comprises yellow shells secured in a great many small islands of the Dutch East Indies, and brought to Singapore by Chinese traders.

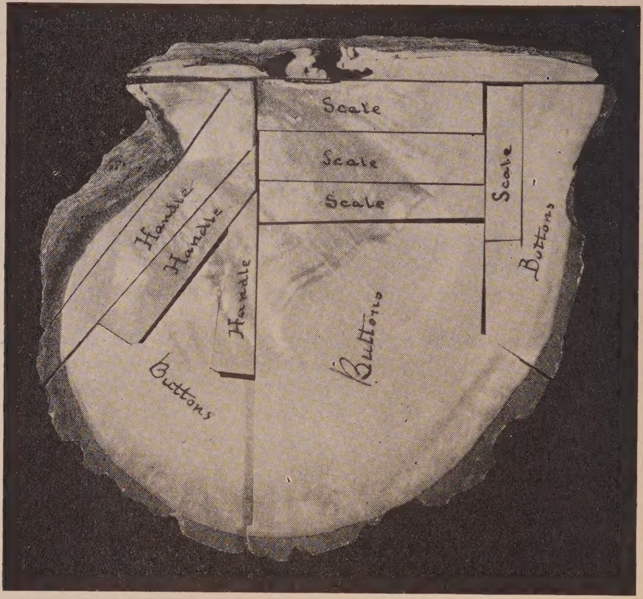
Green Shells—Among these may be counted Egyptians, Bombays, Panamas, La Paz, Costaricas, having a more or less inferior degree of whiteness, often with a greenish tinge, the outer rim or edge being generally of a darkish hue.

Black Shells—These come from the South Sea Islands, the Paumoto Group (Tahiti), the Gambier Islands, and in lesser quantities from many islands of the South Pacific, such as Fiji, Banda, etc.

Mother-of-pearl shells are graded as follows: White shells from Western Australia, Azores and Sydneys are graded in Australia in the following manner: first, AA, 36 pounds per 100 shells; A, 36 to 60 pounds per 100 shells; B, heavy medium, 65 to 90 pounds per 100 shells; C, bold, 100 to 130 pounds per 100 shells; D, good defective; E, rough defective. Yellow shells from Manila and Ceram are sorted in London as follows: Bold, anything over 75 pounds per 100 shells; medium and chicken, anything up to 70 pounds per 100 shells. La Paz and Panama shells are sold in bulk or sorted into sound and defective. Shark's Bay and Lingah shells are not graded. Black shells from Tahiti and Auckland and also Bombay and Egypt are graded thus: A, bold, 70 pounds and upward per 100 shells; B, light bold, 40 to 50 pounds per 100 shells; C, 30 to 40 pounds per 100 shells; D, 18 to 27 pounds per 100 shells.

Manufacture of Buttons.

It is the general opinion that the first production of buttons from pearl shells on a commercial basis took place in Austria about two centuries ago, the material used being Red Sea shells, which had been brought to Austria by way of Constantinople. The industry has grown rapidly and is now the most important button industry as well as one of the principal users of mother-of-pearl. It is centered in the United States, Austria Hungary, France, Germany, England, Japan, Italy, and Spain.



Courtesy American Museum of Natural History, New York.

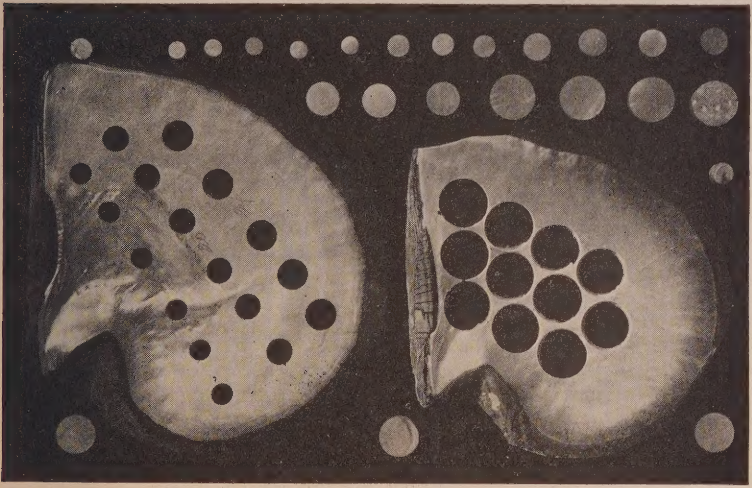
FIG. 55.—Manufacture of buttons. Sections of shell marked off for cutting.

According to the 1914 census of manufactures, the United States produced 21,644,436 gross of fresh-water pearl shell buttons valued at $4,879,844 and 4,516,969 gross of marine mother-of-pearl buttons valued at $2,489,364. The industry is carried on chiefly in New York City and its environs, in Newark, N. J., Philadelphia, Pa., Attleboro, Mass., and Providence, R. I.; there are also a few scattered factories in the western states.

At present, France is one of the leading European producers of mother-of-pearl buttons although formerly large quantities were exported from Austria Hungary and Germany. Great Britain also utilizes much mother-of-pearl for button manufacture.

A great new button industry has been developed in Japan during the last fifteen years, until to-day, Japan is the strongest competitor of France.

In the manufacture of pearl buttons, those of the first quality are made from the part of the shell nearest to the hinge; from this are made the finest shirt and cuff buttons. The thinner parts of the nacreous coating are used for buttons of cheaper quality. As a first step, a disk is cut out of somewhat larger diameter than that required for the button; this disk is cut with a turning lathe. In many European centers of the industry the preliminary work of disk-cutting and polishing is done in a factory; with this material the domestic industry makes the buttons. The disks are reduced to the dimensions required for the button by means of a triangular steel file of fine temper, and with a very obtuse point. On account of the considerable and variable hardness of the mother-of-pearl, only an expert workman can perform the task satisfactorily, for as there is danger that the material may crack, he must be always on the alert to feel the degree of resistance and regulate the pressure of the tool. An expert operator can make from 12 to 22 gross of buttons in a day, according to their size. The perforation is generally done by women, one of

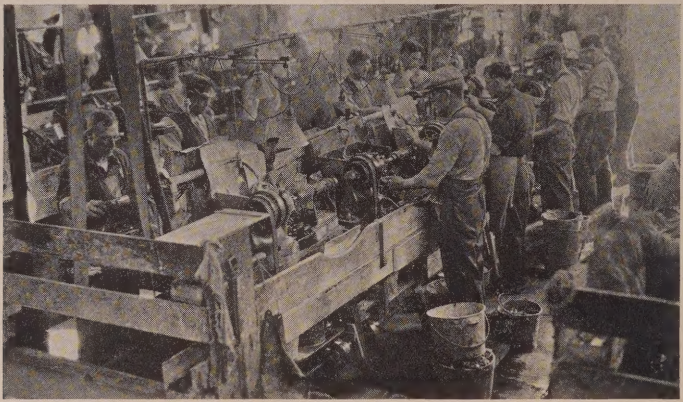


Courtesy American Museum of Natural History, New York.

FIG. 56.—Disks cut from shell of *Margaritifera margaritifera.*

whom can pierce in a day 30 gross of buttons having four perforations. After these operations of forming and piercing, comes the work of polishing, also usually performed by women. The buttons are firmly mounted, and polish is given by a strip of cloth impregnated with highly diluted sulphuric acid, and another cloth covered with tripoli powder. These are passed rapidly over the surface by the power of a turning lathe.

American Methods.—The shells are first sorted by hand according to species and quality. They are then classified as to size by a machine called a classifier. The classified shells are placed into large metal tanks or vats, or sometimes into barrels, in which they are allowed to soak for a week or more, thus softening the shells so that they may be cut more readily.



Courtesy Bureau of Fisheries.

Fig. 57.—Manufacture of buttons. Cutting room.

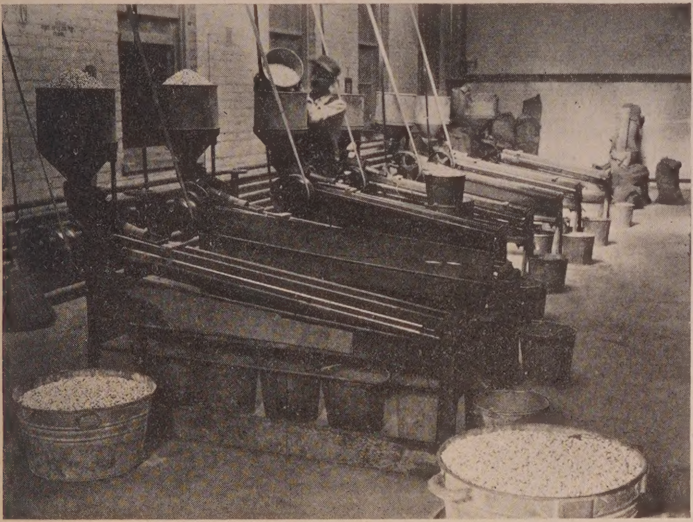
The blanks are cut by means of a lathe fitted with a tubular saw, and with a wooden plug and ratchet handle or lever for gradually forcing the rough shell against the rapidly rotating saw.

The blanks are classified by a machine consisting of variously spaced rollers between which they fall, and are thus separated into different lots according to thicknesses.

They are then placed in tumblers, consisting of heavy, slowly revolving barrels of iron or wood. Here the blanks are churned with water and pumice stone or sand and thus are cleaned.

The blanks are then ground by means of an emery wheel to remove the horny backs and reduce the blanks to a uniform thickness. Finally the blanks are again soaked in water to be softened for the finishing machine. The more modern factories use an automatic machine for making the buttons, which rounds the edges, carves out the center in the desired pattern to make the face of the button, and drills two or four holes according to pattern. These machines finish from 30 to 70 buttons a minute, thus making from 100 to 190 gross per day.

The drilled buttons are again placed in the churns and cleaned with water and pumice to make ready for the final polish, which is also a tumbling process, in which, however, sulphuric acid or other acid is used in conjunction with steam.



Courtesy Bureau of Fisheries.

FIG. 58.—Classifying "blanks" according to their thickness.

Finally the buttons are carefully sorted into twelve grades, and those intended for retail trade are sewed on cards.

Manufacture of Inlaid Objects.

Because it is at the same time hard and splintery, mother-of-pearl is difficult to work. The initial operation consists in freeing the shells from the outer covering, or bark. This can be done either before or after the shell has been divided into the separate pieces which are to be employed for ornamental use. In button manufacture the outer coating is usually removed afterwards, while in other cases it is removed before the shell is cut up.

The separation into sections is accomplished with due care to secure pieces of adequate size for the object for which they are to be used, and to see that these pieces are comparatively free from defects. Only after long practice does the workman acquire the art of doing this properly. The cutting is done with a circular saw of well-tempered steel; the operation is facilitated by the use of emery. The pieces having been cut perpendicularly to the surface, occasion may arise to divide them horizontally into thin plates; but these are more usually secured at once from the thinner parts of the shell near the lip, while thicker pieces are obtained from that part which is near the hinge. Since the thickness of the nacreous stratum differs in the different species of shells, it is safer to secure the thin sections directly, as indicated above, rather than to risk the operation of horizontal divisions of the thicker sections.

The pieces of mother-of-pearl thus obtained are not entirely smooth, nor are the under and upper surfaces absolutely parallel, owing to the curvature of the shell. As a general rule, that side of the mother-of-pearl from which the outer crust has been removed is superior in play of color to the interior side; but not infrequently it is defaced by the existence of cavities, in which case, of course, the inner side is the better.

After the surface of the sections cut out of the pearl shell have been freed of the "bark" and polished, the required form is given them with the lathe; the kind most commonly used is worked by a pedal. The method of working resembles that employed for ivory and bone. The velocity of the wheel must be carefully regulated, for if it revolves very rapidly there is risk of splitting the mother-of-pearl; to preclude the danger of overheating, the material is kept moistened with water during the turning operation.

For the more artistic inlays it becomes necessary to pierce the design on the thin mother-of-pearl plaque, as is done in the case of ivory or tortoise-shell. The design having been executed, an imprint of it, or more often the design itself, is glued on the piece of mother-of-pearl. This is now firmly set in a screw vice, attached to the turning-lathe, and the design is carefully cut out by fine steel saws. Here again it is essential to keep the mother-of-pearl moistened, to regulate the speed of the lathe, and to apply a slight coating of fine wax to the saw. For the more delicate touches, the burin must be used to supplement the work of the fine saw, for with this alone, there is danger that the engraving may lack clearness and sharpness, and appear hacked out. Indeed, as a usual thing the designs are not fully cut out, but are rather given in outline.

At one time inlaying in mother-of-pearl was practiced in great perfection in Ahmedabad, India, but the art has been allowed to fall into desuetude. Examples of this inlaying were to be seen on the wooden canopies over the shrines of Shah Alam at Sarkhej, and on stone in the marble tomb of one of Sultan Ahmed's queens. The simpler designs were made by filing pieces of mother-of-pearl to the required size, and then inserting them into a pattern cut into the block of wood. To secure more varied effects, pieces of different colors were worked into cement, and were attached to the surface which was to be ornamented. The commoner sort of inlaying was still occasionally employed for the adornment of the frames of musical instruments, such as the *tambwas* and *rubabs.*[7]

Cameos.

Mother-of-pearl is also extensively carved into cameos. This art is practiced chiefly in Italy where the chief center is Torre del Greco, near Naples. The shells most commonly employed are of the genus *Cassis,* which are chiefly obtained from the Carribbean Sea and the Indian Ocean.

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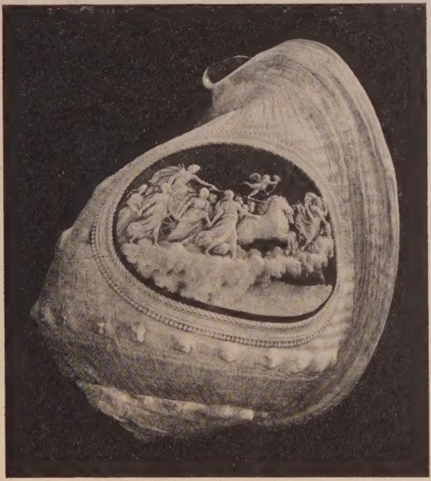
[7] Birdwood, G. C. M., The Industrial Arts of India. London, 1880.

The various species of *Cassis* are of many different colors and are often delicately tinted. Thus cameos of all of the colors in the rainbow may be carved.

Jewelry and Miscellaneous Objects.

Mother-of-pearl finds use in the manufacture and ornamentation of a great variety of objects for household and personal adornment. Much of the very finest grades is cut into handles for knives, opera glasses, umbrellas and many other objects. It is often used for the decoration of fountain pens, clocks, ink wells, picture frames and other valuable things.



Courtesy American Museum of Natural History, New York.

FIG. 59.—Shell cameo from *Cassis madagascarensis.* Guido Reni's Aurora, Rospigliosi Palace, Rome.

Jewelers use it often for the manufacture of belt buckles, combs, bar pins, beads, studs, cuff links, hat pins, etc. The pearl obtained from abalones is a favorite among jewelers.

A special use of mother-of-pearl is that sometimes employed to produce a coarse variety of mosaic, denominated in France *nacré chinois.* The object is to impart an iridescent sheen to the surface, usually of metals; in Naples it is much in use for iron bedsteads. The design having been drawn in varnish on the iron, the iridescence is imparted by attaching, with the same varnish that is used to render the design brilliant, very thin layers of mother-of-pearl. In Japan, similar but more carefully executed work is done on lacquer, and the interior surface is lined with layers of pearl or coatings of pearl powder, forming designs of flowers, fruits and other ornaments.[8]

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[8] Orilla, E., La Madraperla e il suo uso Milan. 1908, 158-9.

In India, the chank shell is held sacred by the Hindus, and is utilized in a great number of curious ways. In Bengal, every married woman of all castes which are thoroughly Hinduized is bound to possess a pair of chank bangles (bracelets) lacquered in vermilion as one of the visible tokens of her married state. In many other parts of India chank bangles are worn to designate the caste to which the wearer belongs. Chanks are used in many religious ceremonies including marriage and death rites by all castes of Hindus; they are also used medicinally for the treatment of a number of diseases. Powdered chank shell is one of the Hindu "cures" for tuberculosis.

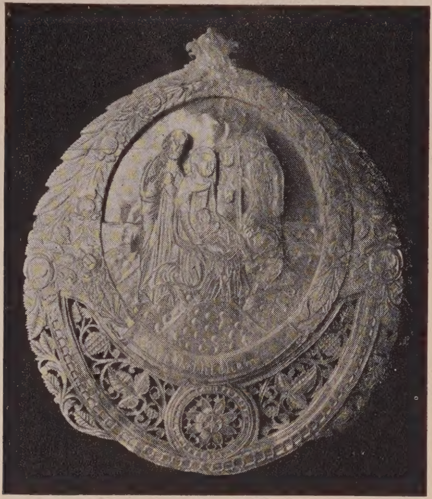

FIG. 60.—"Jerusalem shell." Pearl shell with religious design, sold in Holy Land.

Preservation.

Mother-of-pearl beads and other objects sometimes become soiled or lose their lustre. In many cases they may be cleaned by the use of a soapy, warm water solution, to which a few drops of ammonia have been added. The liquid can be applied with an old toothbrush.

If, however, the beads become stained they can scarcely be restored, but if they have merely become roughened, or have lost their lustre, re-polishing them with a paste of sulphuric acid sometimes restores them, the polishing being done with a circular felt buffer or a hand buff. If the beads are strung when the ammonia water is applied, each bead should be wiped off with a bit of chamois or tissue paper that has been dipped in the cleansing solution. If, however, they have not been cleaned for a long time a regular crust may have formed over the pearl beads, produced by powder or cosmetics. As much as possible of this should be carefully scraped off before the ammonia water is applied.

Blister Pearls.

Origin.

The term "blister pearls" is used for those which develop on the shell of the pearl oyster. They owe their origin to the defensive or protective action of the mollusk in resisting the intrusion of some animal, such as, for instance, a boring sponge or a burrowing worm, which has begun to penetrate the outer layers of the shell, or by the intrusion and presence of grains of sand, or similar material between the mantle and the shell. To allay the irritation caused thereby, the mollusk deposits nacreous material upon the spot, and the accumulation of this forms a little mound which closely resembles a segment of a large pearl. This excrescence conforms to the shape of the irritating object, and when this was large and very irregular the blister is of similar form. In some cases it results from the mollusk covering a choice pearl which has become loosened from the soft tissues and adheres to the shell, and which may be secured by breaking the blister.

The blister pearls [9] found on the abalone shell are formed chiefly in defense of the invading, boring mollusk *Pholadidea parva.* They occur mostly in the red abalone, with only one blister pearl in about 1,000 shells of the green or black species. A crab, which infests the abalone at certain seasons, may be the cause of such formations, and one has been found which exhibited the complete outline of such a crab. Frequently the blister pearls are found over sea urchin spines, chiton, or razor clam shells, pebbles, and other foreign bodies retained beneath the surface of the mantle. Sometimes a diseased visceral lump is cut off and covered by nacre, making a huge blister pearl.

Although pearl blisters frequently give the effect of being empty, they are usually filled with some fluid resulting from animal and vegetable decomposition. When a pearl shell shows any protuberance on the surface, the peeler will cut or scrape away a portion of the decaying shell behind the spot. If he finds it to be perfect, and not the hole of a boring insect, this proves that the protuberance has been forced out from within, and it often proves to be an included pearl. This is then removed by breaking the shell, or by cutting around the protuberance very near to its edge and then breaking away the shell. Layer after layer of the covering mass is removed by the peeler, with the greatest possible care, and not infrequently he is rewarded for his labor by the finding of a very valuable pearl.

Closely resembling the "blister pearls" are those known as *bouton* pearls. In this case, the pearl-forming sac becomes ruptured and a pearl growing in the tissue of the mollusk, very near to the nacreous lining of the shell, gradually becomes attached to the shell, whereby the growth of the under side is arrested; while on the upper, exposed surface, further coatings of nacre are deposited. This results in the formation of a

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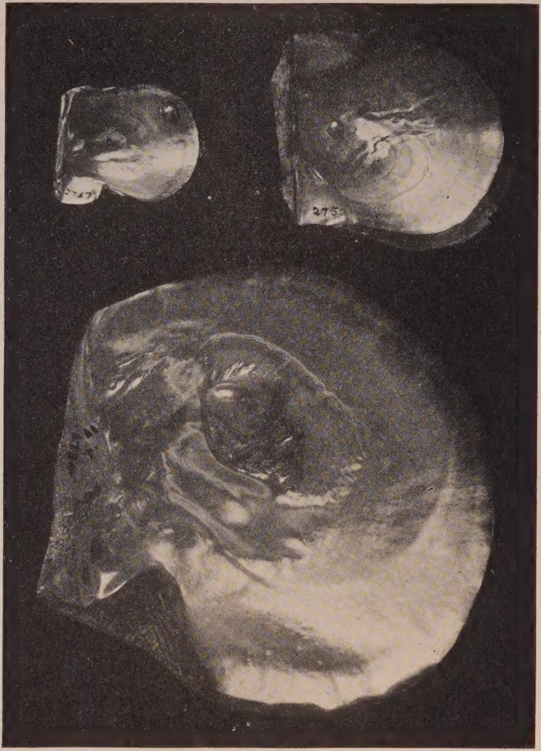
[9] Edwards, C. L., *Smithsonian Institution, Rept.* 1913, 429-438.

"button"; the constantly growing shell finally encloses the pearl, which in some cases is forced backward until it is pushed through and out of the shell. From this source are derived great numbers of half and quarter pearls, usually faulty and of indifferent lustre.



Courtesy American Museum of Natural History, New York.

Fig. 61.—Encysted pearls in shells.

2783	Oriental pearl shell.
2767	Oriental Bombay.
2734	Costa Rica, C. A.

While the chemical composition of these pearls is the same as that of those regularly found in the mollusk, the physical properties differ to a certain extent, for the nacreous layers in the true blister-pearls lack the regular concentric disposition characteristic of spherical pearls, and the same holds good of the outer layers of the encrusted pearls.

Utilization.

In America the only important source of blister pearls is the abalone shells. In 1912 over 86,000 blister pearls were obtained from these fisheries.

Blister pearls are utilized in jewelry in many ways. Beautiful pins and brooches are made from them. The finest are often mounted in rings. Blister pearl cuff links are much in vogue.

These pearls have been worked into fantastic figures using pearls and other jewels for parts of the designs. Some of the most beautiful designs are to be seen in the famous Green Vaults' Collection in Dresden. One of the most curious of these is the figure of a dwarf formed of a baroque pearl, studded with small diamonds.

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Chapter 10.

The Precious Coral Industry.

By GEORGE FREDERICK KUNZ*

History of the Coral Industry.

The use of this wonderful organic product for personal adornment dates back to very early historic times. Theophrastus, writing in the third century B.C., terms it a stone of blood-red color, but having a cylindrical form like the root of a plant, and growing in the sea. In Roman times the finest coral was that taken near the present Hyères Islands off the Mediterranean coast of France, and at the Lipari Islands, as well as off Trapani in Sicily. Among the ancient Gauls coral shared with amber in favor, indeed, these were their only costly materials which they used for jewels. In the Roman world, and elsewhere, superstition added something to the favor enjoyed by coral, for following the theory of sympathetic medicine, the blood-red coral was believed to cool the human blood, and reduce inflammation. Moreover, the little branches of coral were supposed to neutralize the dreaded magic of the Evil Eye. Even up to a rather late period, almost to modern times, coral was ranked as one of the precious stones and classed as such by all the writers on precious stones.

The great French gem-dealer of the seventeenth century, Tavernier, in his Oriental travels, had opportunity to learn of the esteem in which coral was held by the Japanese of that time, and he says that while they neither valued pearls nor precious stones, they greatly prized beads of coral, on which they strung the silken cords for closing the bags they were so fond of carrying. If for this purpose they were able to obtain an especially large coral bead, one the size of an egg, and of a pure clear rosy hue, they were ready to pay whatever was asked for it. Indeed, he says that he learned from the Portuguese traders that as much as 20,000 crowns (about $22,000) could be obtained for such a bead.[1]

Importance of Industry.

Prior to 1880, the annual product of the coral fisheries brought to Torre del Greco, Italy, averaged about 300 quintals, worth about $100,000. From 1880 to 1885 the product was largely increased, reaching about 2,000 quintals, worth $600,000. In the year 1914 the quantity was about

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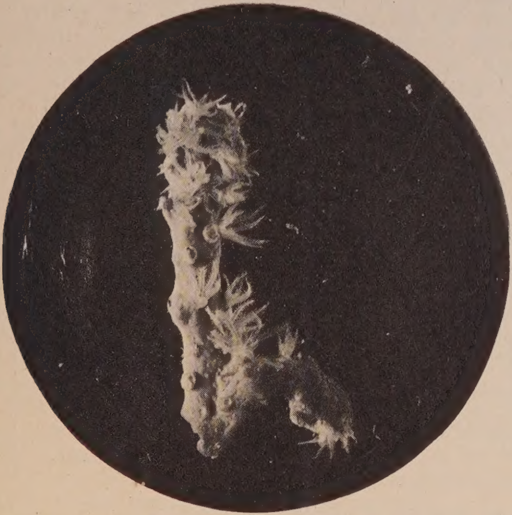
[1] Bell, V., Travels in India by Jean Baptiste Tavernier, Baron d'Aubonne, *2*, London, 1888.

600 quintals, valued at 800,000 lire, or nearly $160,000. The most valuable coral is that brought from Japan, the annual quantity ranging from 50 to 100 quintals, worth from two to three million lire, $400,000 to $600,000. These figures combine to show a wide range of prices for the different qualities of this beautiful substance. The exports of worked coral from Torre del Greco were valued at about 10,000,000 lire annually, from 1880 to 1885. The bulk of these exports went to India.

Nature of Coral.

Living Coral.

Formerly it was believed that coral belonged to the plant kingdom and was a peculiar sort of seaweed. Modern biologists have found that it bears no resemblance to plants except in form, and that a single, complete branch of coral bears a great number of organisms, the polyps, which form a sort of colony. During the life of these animals the red calcareous material of the coral branch is covered with a thin, fleshy, reddish rind, termed by zoologists the cœnenchyma. In this the polyps are embedded, and they are easily distinguished by their white hue. They secrete the lime which serves to build up the structure of the coral branch. The coral branches do not seek the light as plants do, but spread horizontally along the basis to which they are firmly attached. The fleshy rind covers the entire coral up to the ends of the branches, which are therefore soft and pliable, and can be severed with a sharp knife, while this is no longer possible further down the branch. If a living coral-branch is allowed to



Courtesy American Museum of Natural History, New York.

FIG. 62.—*Corallium rubrum.* Expanded polyps of precious coral on branch.

dry in the air, the skin, or rind of a brick-red hue hardens, and little protuberances are to be seen upon it here and there. These have a round aperture in the center, from which ray out eight short ridges; in these protuberances the polyps lie embedded.

The greater part of the coral-producing organisms belong to the actinozoan division of the Cœlenterata, the sole exceptions being the hydrozoan staghorn coral (*Millepora alcicornis*), and its congeners. There are two divisions of the coral producing Actinozoa, namely, the *Octocoralla,* in which the animal is eight-rayed, and the *Hexacoralla,* or six-rayed. The first named class comprehends the "sea-fans" and "sea-whips," *Gorgonia* and *Muricea,* of the southern coast of the United States, and the precious coral of the Mediterranean region.

The Coral of Commerce.

The specific gravity of coral closely approaches that of calcite, ranging from 2.6 to 2.7 but its hardness of 3¾ is a little greater, owing to its slightly different composition. This low hardness facilitates the carver's or turners' task, although coral does not take a fine polish, its beauty of hue makes up for this to a considerable extent; although not very hard, the material has some toughness and tenacity and wears well.

Being slightly opaque or sub-translucent, scratches do not show. Since it is composed chiefly of calcium and magnesium carbonates, acidulous perspiration affects the surface of precious coral.

The respective composition of red and black coral has been determined as follows from typical examples:

	Red Coral	Black Coral
Calcium carbonate	86.974	85.801
Magnesium carbonate	6.804	6.770
Calcium sulphate	1.271	1.400
Ferrous oxide	1.720	0.800
Organic matter	1.350	3.070
Water	0.550	0.600
Phosphoric acid (P_2O_5), Silica (SiO_2), etc.	1.331	1.559
	100.00	100.00

From these analyses it appears that black coral differs from red chiefly in the content of organic matter. Various observers have concluded that the color of the black coral is due to the presence of this organic matter. Several writers have said that the red color of precious coral is caused by its iron content. The latter conclusion does not seem probable as the red color is destroyed on ignition, just as is the black. The red coloring matter is presumably an organic compound formed by the polyps.

Coral Fishing.

Location of Industry.

The most important and profitable coral banks are those on the Algerian and the Tunisian coasts. The former extend eastward from Cape Ferro (Cap de Fer), a little west of Bona, toward Cape Bon, and thence in a southerly direction to the Gulf of Gabes in the region of Sfax. The coral fisheries are prosecuted up to six or even eight miles into the sea, and at depths between 90 and 900 feet. It has been found that corals taken from a considerable depth are paler and less lustrous than those from lesser depths. In these regions the fisheries have been carried on for centuries, with greater or lesser activity. In former times the great place of assemblage was the island of Tabarca, near the coast, at about the boundary between Algeria and Tunis. Even in our day this island, and the island of Galita not far removed, are still frequented by the coral-fishers, but the most important station is now the coast town La Calle, where much has been done by the French Government to further the industry. Other centers are situated on the Cap de Garde and the Cap de Fer and at Sidi Mansur opposite the Kerkenna Islands in the Gulf of Gabes.

Coral banks rivalling those of Algeria and Tunis, are on the coast of Sicily, the most productive being near Sciacca, west of Girgenti, which have been actively exploited for the past forty or fifty years. At Sciacca the banks are at an average depth of about 650 feet. A curious characteristic of these banks is that the coral polyps are all dead. As a result, many of the corals have lost their fine red color. This deterioration in quality has been continuous since the discovery of the banks in 1875. The cause is believed to be a slimy deposit which interferes with the inflow of fresh and pure water on which the animals depend. This deposit is presumed to have resulted from a violent submarine eruption in 1831.

The control of the coral fisheries on the Mediterranean was for a long time a source of lively dispute. At an early period the Italian republics were the predominant factors. With the rise of the French power following the French Revolution and the invasion of Italy, France gained the control, and the French coral industry, which had been essentially confined to Marseilles, was extended to the Italian establishments in Naples, and also in Rome and Genoa. With the passing away of the Napoleonic Kingdom of Italy, the Italians regained control, indeed the work had all along been done by Italians. This, however, does not refer to the extensive fisheries off the coast of Algiers and Tunis, which are in the hands of the French, although much or most of the coral is eventually worked into ornamental forms in the Italian centers of the industry.

The coral fisheries at Mers-el-kharez, near to Bona on the north African coast, were highly renowned in the Middle Ages, as were also those along the Sicilian coast, and off Sardinia and Corsica. A certain portion of the output of these fisheries remained in the Occident, where it was worked up into ornaments of various kinds, but the larger part was exported. Coral was highly prized in southern Africa and about two-thirds of the production were sent to India and Indo-China. Among the Arabs it was well known that coral could be exported to these countries at a profit, and when the Portuguese began to establish themselves in this region, they found that it was in great demand. The ships of Catalonia and of Florence bore it to Egypt, where it was disposed of to the oriental merchants.[2]

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[2] Heyd, W., History of the Commerce of the East in the Middle Ages (French), 2, Leipzig, 1886.

Coral is also found off the small islands north of Sicily, Ustica and the Lipari, but a more important coral fishery is in the Strait of Messina. However, the chief center of coral production, after the north African coast, is off the islands of Sardinia and Corsica, only on the western, not on the eastern side. The richest field is the Strait of Bonifacio, between Sardinia and Corsica. On the Sardinian side may be noted the islands of Asinora, and the neighborhood of the islands Maddelena and Caprera.

Off Jedda in Arabia, in the Red Sea, there is a black coral fishery extending for fifty miles north and south. This black coral is carved into beads, and mouthpieces for cigar holders. That of a dull white hue is less hard than the black, and as it does not take a good polish it is sold cheaper. Moreover, it is often deteriorated in quality from being worm-eaten.[3]

The Japanese coral fisheries are very productive and the quality of the material secured is very high, both of the choice white coral and of the deep red, or Moro coral. These fisheries furnish valuable imports to near-by China, and large quantities are also sent to Torre del Greco, Italy, and other centers of the coral industry.

The World War made itself very unfavorably felt in the Italian coral industry; coral fishing in the Mediterranean, and the importation of Japanese coral were paralyzed. The Japanese home industry did not fail to profit by this circumstance. A report from U. S. Consul H. Earle Russell in Rome states that to confront this competition the Italians largely increased their coral fleet, and that motor boats for the fishing were assembled in the waters of Algeria, Tunisia, Dalmatia, Greece and Turkey, negotiations being carried on with those countries to secure fishing rights.

Methods of Fishing.

Mediterranean.

The coral fishery is carried on during the six months of spring and summer, although in some regions it continues all through the year. As a rule, however, the autumn and winter storms render the operation too dangerous. The boats used for this task are solidly constructed and good sailers; they are provided with oars which can be used if required. In size they commonly range from 6 to 16 tons, the largest ones having a length of about 45 feet, a beam of about 11½ feet, and a depth of about 6 feet. They are manned by from six to twelve persons, who have eighteen hours' hard work daily for small pay. They carry a large lateen sail, and a jib and staysail. Most of the boats are owned by Italians, and these bear the produce to Messina, Genoa, Leghorn and Naples, where the coral is bought by the carvers and jewelers. A certain number of smaller boats, of only from 3 to 6 tons burden, sail under the French flag, but the crews are almost entirely composed of Italians; these smaller boats keep at the work for the greater part of the year, but not many of them are now employed. One of the larger boats may collect from 600 to 650 pounds of coral in the season.

[3] Simmonds, P. L., The Commercial Products of the Sea, London, 1883.

A small amount of coral is collected by divers working from small boats near the shore where the water is not over ten feet deep; but the largest and most beautiful coral grows in much deeper water and is inaccessible even to fully equipped divers.

To obtain the coral lying in deep water, the coral fisheries of the Mediterranean use a specially constructed instrument which is called *ingegno* by the Italians and *engin* by the Provençals. It consists of two cross-pieces of solid oak, the length of the instrument varying, according to the size of the fishing bark, from one to two and a half, or even more meters. The two pieces are firmly bound together in the middle and so disposed as to form four long arms tapering toward the ends. At the point of contact in the middle is attached a heavy stone, a piece of lead, or some other weighty object, which causes the "engine" to sink in the water. In recent times the oaken arms are quite often set in an iron centerpiece. Each of these four arms is encircled by a groove along which passes a cord from six to eight meters long; one end of it is fastened, and at the intersection of the arms is attached a fifth and still longer cord. To these cords are bound at regular intervals the actual implements for seizing the coral. These are very coarse-woven, square nets, with a mesh of several centimeters wide, made of loosely twisted hemp-twine as thick as a finger. In all there may be from 30 to 40 such nets on a machine. Alongside of the coarse-meshed nets hangs one of finer mesh, commonly made from old nets used in sardine fishing.

The machine, which is fastened to the bark by a long rope, is cast into the water, and the nets spread out so as to cover a considerable surface. The weight of the machine carries them down to the bottom and the coral plants become entangled in the meshes, the larger pieces being caught by the strong, wide-meshed nets, while the smaller pieces fall into the fine-meshed nets. Of course many other materials are brought up, such as pebbles, marine plants, etc., when the nets are finally drawn up, after they have been allowed to drag along the bottom in the wake of the bark for some time. The time needed for operating these machines is considerable, and as a rule the process of sinking, raising, and cleaning out the nets can only be repeated six or seven times in the course of a day.

Japanese Methods.

In Japan coral is found chiefly in the southwestern waters affected by the warm current, especially in the seas of Satsuma, Tosa, and Hizen. Here it grows upon rocks thirty to a hundred fathoms under the surface. The annual output averages 60,000 pounds valued at about $600,000.

Small boats manned with three or four men are used for the fishing. The implement used is a very simple, strong, net about 5½ by 6 feet, attached at one end to a bamboo pole 6 feet in length. At each end of the pole is a small net of ropes, five fathoms long, and under these nets ten similar nets are hung by means of ropes, each five feet long. Below the ten nets, three nets are hung by means of brass wire and seven-fathom ropes. Each of these nets has a stone weight of 1½ pounds and a 2½ pound stone is attached to the middle of the bamboo bar, to which four ropes, each of seven feet, are tied so as to keep the nets in equilibrium when tied together and dragged over the bottom by a rope one hundred or more fathoms in length. When the nets are drawn over the coral reefs by the men in the small boats, the first net brushes the coral off the rocks and the other nets catch it and bring it up to the surface.

Grading of Coral.

Coral, as it is obtained by the fishermen, is called rough coral, and, before being marketed, it is sorted into four grades as follows:

Dead or Rotten Coral.—This consists chiefly of the lower portion of the main stem and the disc-like "foot" of the coral stock. When the outer crust is removed, valuable pieces of coral are often found. Often the broad foot-plates are worked into small dishes and bowls.

Black Coral.—This includes coral in which the black color extends through the whole or a large part of its substance.

Common Red.—Red coral of all kinds, with the exception of the pieces of exceptional size, are placed in this class. It embraces alike whole stocks and broken fragments irrespective of form and size.

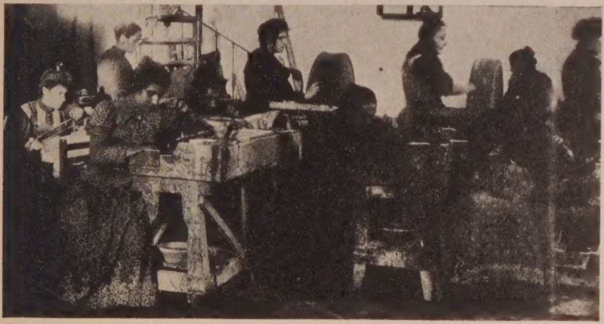
Selected Pieces.—Pieces of exceptional size or beauty are selected from the ordinary red coral and are sold as selected pieces either separately or in parcels and bring very high prices.

The Working of Coral.

The working up of coral into ornamental objects is mainly done by Italians, who are also most largely engaged in the coral fisheries. The industry is also carried on, though much less actively, in Spain and France. It has been estimated that there are some 600 establishments for this work in Italy, employing about 6,000 men and women. In this industry, as well as in coral-fishery, Torre del Greco occupies the most prominent place, for here alone there are counted as many as 40 workshops with 2,800 women workers and 400 male workers. Also in Genoa, Naples, Leghorn and Trapani, the industry is carried on to a greater or lesser extent.

The principal use of the coral material is for beads to be strung as necklaces, as bracelets or armbands, or as rosaries. The beads are made either of spherical or oval form, and toward the beginning of the last century they were not infrequently facetted, but this fashion has since disappeared. The Italian carvers are also very deft in executing little coral cameos, with floral or animal designs and sometimes with human figures. They are very ingenious in utilizing the inequalities and even the imperfections of the material to produce striking effects. These objects are often set in the handles of brushes or hat-pins, or else they may be strung on necklaces. Polished ends of the coral branches are utilized for watch charms, and a peculiarly Italian use of these forked branches is to exorcise the influence of the Evil Eye, the Jettatura so much dreaded by many Italians.

The Royal School for Coral Engraving at Torre del Greco, near Naples, was founded by decree of June 23, 1878. Instruction is given both to day and night classes, as to technical and artistic engraving on coral, lava, shells, tortoise-shell, ivory, hard woods, metals, etc. The instruction is imparted gratuitously, and all the necessary material is furnished without charge, but remains the property of the institution. To graduates a good part of their work in designing and decorating is given, as are also some clay models of plastic designs and engraving. The entire course lasts four years. In the first year the pupil attends preparatory classes in designing; in the second year there is more advanced instruction in designing; and at the same time instruction in plastics, or in engraving and inlaying; in the third year comes the first course of applied design and the second course of plastics, or of engraving and inlaying; the fourth year is devoted to finishing these different branches.[4]



Courtesy Commendatore B. Mazza, Torre del Greco.

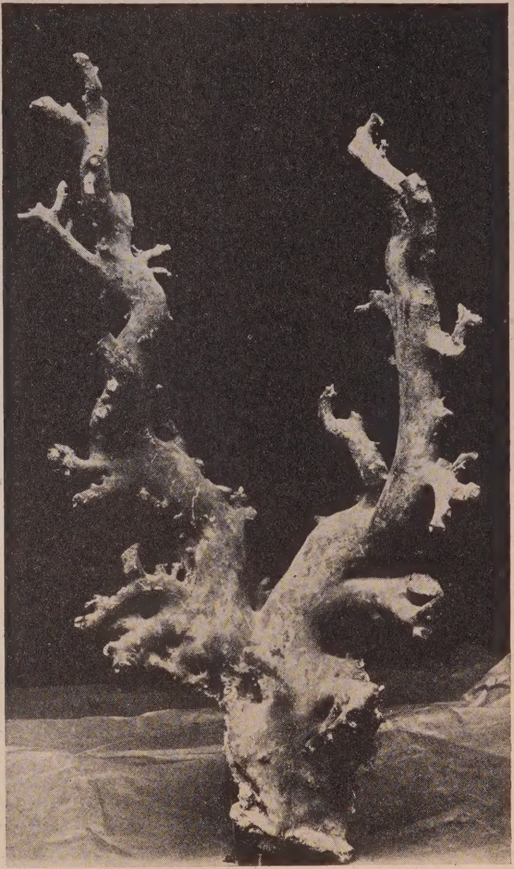
FIG. 63.—Drilling precious coral and shaping it roughly. Workshop at Torre del Greco, near Naples, Italy.

The artistic Japanese carvers have displayed their skill on the beautiful coral which is fished in Japanese waters, and some exceptionally fine specimens of this work have been recently offered for sale in London. The carvers have very successfully utilized all the color-qualities of their attractive material, which came from fisheries at Tosa. The work was principally executed at Tokyo (formerly Yeddo) for Lord Matsumae, Daimyo of Yedo, by the artist known as Kimba. The collection was begun in 1851 and finished in 1902. The subjects are of great variety, including representation of divine beings, such as the Goddess of Beauty (Benten-sama), holding a jewel and riding on a dragon, done out of pink coral; this is valued at over £1,000. Then there are warriors and wrestlers, besides many fine animal pieces. One of the most costly of these carvings is of the God of Health (Daikoku), one of the seven gods of luck, in dark salmon-pink coral, valued at £600. There is also carved from a fine piece of white and pink coral, a warrior of the time of the Ashikaga Shogun; the dauntless hero is committing suicide in expiation of his undeserved defeat in battle. This fine and varied collection illustrates what splendid effects a true artist-carver can realize with coral.

[4] Enrico Orilla, Mother of Pearl and Its Utilization in the Industries and Arts (Italian), Milan, 1908.

Utilization in Jewelry.

As objects of personal adornment coral beads and other coral ornaments are much more highly favored in the Orient than in the Occident. However, in some parts of Italy, as well as in the territory of the former Austrian Empire, in Poland, and more especially in Russia, coral jewelry is much fancied. In Turkey, coral is not only used for the adornment of men and women, but it is also inlaid in the decorated walls of rooms, and is employed freely for many objects such as pipes, weapons and the



Courtesy Commendatore B. Mazza, Torre del Greco.

FIG. 64.—Mass of Moro coral from Japan. The deep-red, ox-blood variety. Weighs 100 pounds and was valued at $25,000 at the St. Louis Exposition.

trappings of horses. In north Africa generally, with the exception of Egypt, where it is not much esteemed, coral enjoys great popularity, and this is also the case in Arabia. The Persians appreciate it highly and the same is true of the Chinese and the Japanese, while in India, and in Thibet it ranks among the best fancied materials for jewelry. In India it is set in amulets, necklaces and garters, and has a religious use as a gift to the dead, as it is believed to keep evil spirits aloof from their bodies. It has been aptly remarked that a fondness for coral indicates a certain degree of culture in a race, for the attempts made by traders to substitute coral beads for glass beads in bartering with savage or semi-civilized peoples have not been successful, the "untutored mind," and eye, greatly preferring the sheen and sparkle of the vitreous surface.

The clever trader is often able to utilize some local superstition to his advantage. While the finest of the large and perfectly shaped coral beads were sent to China where they were in great demand for buttons on Mandarins' official caps, many tons of worm-eaten beads found a market in India, because certain of the natives entertained the belief that spirits took up their abode in the little cavities of the coral. Thus what was almost worthless in Europe found a market in India.

Coral jewelry has gradually become more and more popular until at present it is extremely in favor. This refers principally to the pure white Japanese coral, but the white in which each bead has a small spot of pink is still more appreciated; also pink of the palest, most delicate tint is much admired, a single necklace being valued at from $1,000 to $5,000. About 1920, deep red Moro coral, or ox-blood shade, came into vogue; plaques of black-onyx were set alternately with deep-red coral thus offering an effective contrast. Ear-rings of pear-shaped coral, and onyx or coral rings hanging from chains of tiny diamonds also became fashionable. This was a gradual development from the black and white colors, an outcome from the mourning of the great World War.

The price of coral [5] varies widely, according to its size, perfection and color. In the London market the finest tints of rose-pink command from £80 to £120 an ounce (from $400 to $600), but the ordinary red pieces bring only £2 ($10) an ounce, while the small fragments designated as colletts, and which are employed for the making of children's necklaces, can be had for 2 to 5 shillings an ounce, or from 40 cents to one dollar a string.

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[5] The thanks of the author are due to the late B. Commendatore Mazza and Cavaliere Mazza for much information presented in this section.

Chapter 11.

Characteristics of Marine Fishes.

By SAMUEL F. HILDEBRAND*

Definition.

A great many kinds or forms of animals which have little in common, other than that they live in water, are called fish. Thus the name "shellfish" is applied to certain crustaceans and mollusks. The crabs, lobsters, shrimp, oysters and clams, for example, are spoken of as shellfish. Then too, we have the much used names, "star-fishes" and "jelly-fishes." All of these so-called "fishes" are almost totally unlike the forms, which for present purposes, will be termed *true fishes.* The true fishes may be described as cold-blooded, back-boned animals which live in the water, breathing by the means of gills, and having the limbs represented by fins, or rudiments of fins. The skin usually is covered with scales, but these may be replaced by bony plates or rough tubercles, and rarely the skin is entirely naked.

The fishes may be roughly divided into two groups, namely, cartilaginous fishes, *Selachii,* including the sharks, and skates and rays, and the bony fishes, *Teleostomi,* which include practically all the other fishes.

Anatomy.

Form or Shape of Body.—The form or shape of the body in fishes varies greatly. The eels, for example, usually are long, round and snakelike. Such fishes are capable of entering small crevices and holes among rocks and debris and of penetrating dense vegetation. It is even claimed that some eels travel short distances overland. The cod, mackerel, weakfish, and in fact the majority of our important food fishes are fusiform, i.e., the body is roundish and tapers both toward the head and the tail. A body of this shape obviously offers a minimum amount of resistance in proportion to its size in swimming and it permits of great speed. The butter-fishes, the angel-fishes and several others are greatly compressed, the body in some species being quite as deep as long. Fish of this shape clearly cannot enter very shallow water, but they can get into crevices among rocks and debris, etc., and the strongly compressed body does not hinder rapid swimming.

The skates and most of the rays, too, are very thin and flat, but in the opposite direction from the butter- and angel-fishes, i.e., they are depressed. Such fish usually lie close to the bottom, they have an inferior mouth and obtain most of their food from the bottom. The flat-fishes, such as flounders and soles, are compressed but they differ from all other fishes in that they swim on one side instead of vertically, with belly down. They, furthermore, differ in having a twisted skull with both eyes on one side of

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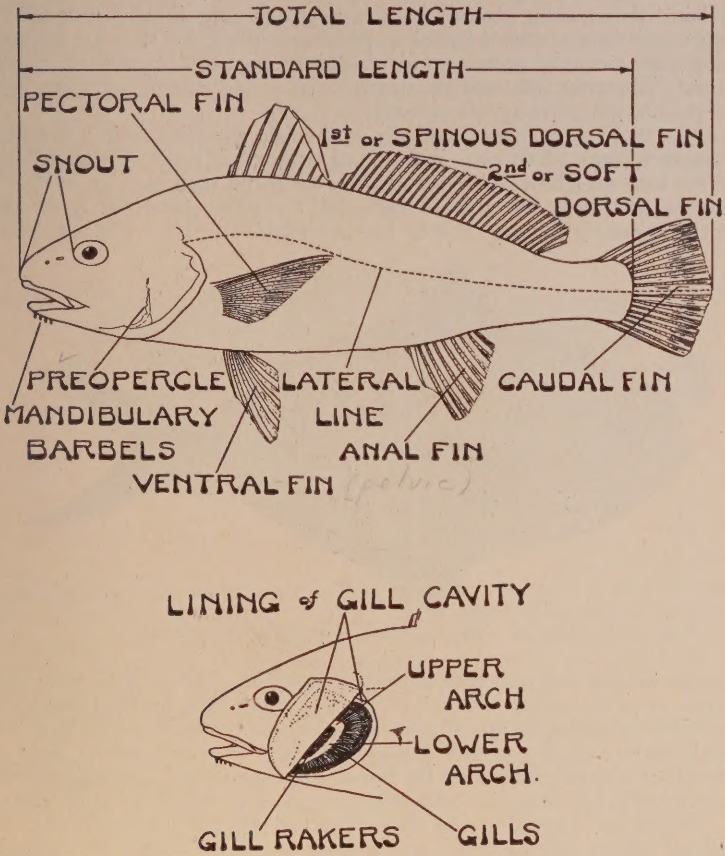
* Ichthylogist, U. S. Bureau of Fisheries.



Courtesy Bureau of Fisheries.[1]

FIG. 65.—Diagram of the croaker, *Micropogon undulatus,* showing the names of the external parts of the fish.

the head. In the young of these fishes, however, the skull and eyes are "normal," but as the fish develops, the skull gradually twists and the eye situated on the downward side of the head, as the fish assumes a horizontal position in the water, slowly moves to the upper side or toward the light. The eyes are either on the right or the left side, according to species, all the fish of one species having the eyes on the same side of the head.

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[1] The illustrations for this section were all obtained through the courtesy of the Bureau of Fisheries.

In addition to the forms already discussed, the almost globular fishes, such as the puffers, the bur- and porcupine-fishes may be mentioned. All of these fishes are capable of inflating themselves either with air or water or both, thus making themselves almost as round as a ball. Fish of this shape obviously are not adapted to rapid swimming and they are provided with other means of protection to which reference will be made on another page. Numerous intermediate shapes exist in our waters, each fish being adapted to the peculiar life it leads.

The Body Covering.—The body of the fish, as indicated in a preceding paragraph, may be covered with naked skin, as in some of the catfishes, or the skin may bear some bony plates, as in the sturgeons, or it may be covered with bony tubercles or denticles, as in the sharks, or as is much more frequently the case, it may be covered with scales. The scales vary greatly in size and structure among the species. Some fishes have large scales, as in the tarpon, *Tarpon atlanticus,* others have medium size scales, as in the spotted weakfish, *Cynoscion nebulosus,* and still others have very small scales, as in the cod, *Gadus callarias.* In some species they are wholly or in part imbedded in the skin. The common eel, *Anguilla rostrata,* for example, has elongate scales which are entirely imbedded in the skin.

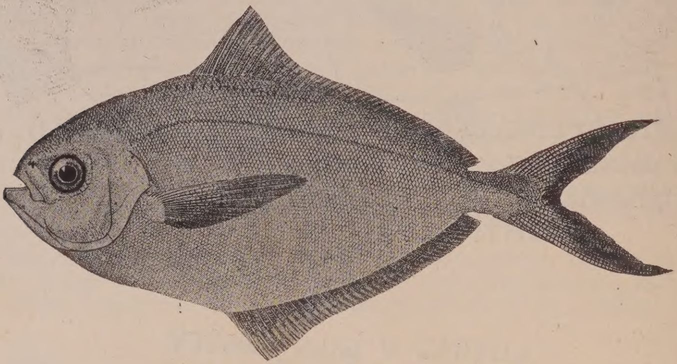

Fig. 66.—The butterfish, *Poronotus triacanthus.*

Scales, for convenience in classifying fish, are mainly divided into two general groups, viz., smooth or "cycloid" scales and rough or "ctenoid" scales. Cycloid scales are those which have the posterior, or free edge, smooth, and ctenoid scales have the posterior edge indented and provided with teeth of various sizes. Scales also bear rings, "circulæ" which may be very close together or somewhat farther apart. In general, when a fish is gaining growth rapidly circulæ are formed farther apart than when growth is gained more slowly. Thus during the summer when the weather is warm and foods are plentiful the fish grows rapidly and the circulæ are formed rather far apart, but during the winter when growth is retarded the circulæ are formed much closer together. It is now possible, through the careful study of these scale characters, to determine with a considerable degree of accuracy the age of certain fish, particularly of the salmon and trouts, and it can be safely predicted that such studies in the near future will enable us to determine the age of a given specimen of many of our common food fishes.

The body covering in some species is provided with structures which provide much more effective protection than ordinary scales. The porcupine fish, *Diodon hystrix,* for example, has the entire body beset with sharp bony spines which lie smoothly against the body when the fish is at ease, but the moment the fish becomes excited the body is inflated and the spines are erected and they meet the enemy as so many sharply pointed bayonets. This fish is of the globular form, previously mentioned, and it is not a rapid swimmer, hence it perhaps has been provided by nature with other means of protection. The trunk-fishes, too, are well protected, although their armature is very different from that of the porcupine fish. The trunk-fish, *Lactophrys tricornis,* for example, exclusive of the tail, is completely covered with solidly united bony plates which form a continuous armor. In addition to this bony armature, a strong spine, directed forward, is situated above and in front of each eye and another on each ventral ridge, directed backward.

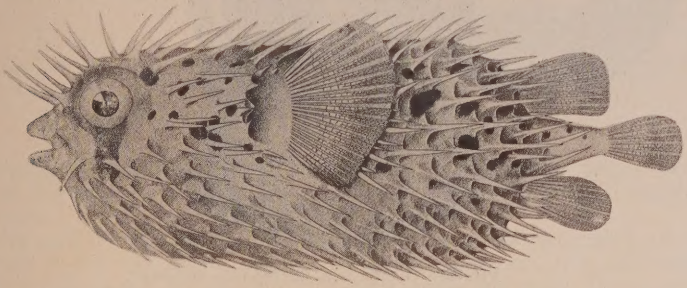

Fig. 67.—Porcupine fish, *Diodon hystrix.*

The Fins.—It already has been pointed out that the modified limbs of fishes are called "fins." These organs vary in number and vary greatly in size and structure among species. A common arrangement is that found in the shad, *Alosa sapidissima,* which has one fin on the back, consisting of soft rays only, known as the "dorsal fin." The tail fin is called the "caudal fin," the fin just posterior to the vent is known as the "anal fin" and besides these so called "vertical fins" the shad has two sets of paired fins. The pair inserted below the shoulders, corresponding to the forelimbs of the higher vertebrates, are called "pectoral fins" and the pair situated on the abdomen, which correspond to the hind limbs of higher animals, are known as "ventral fins." Many fish have more than one dorsal fin. The mullets, *Mugil cephalus,* for example, have two well separated dorsal fins, one consisting of spines and the other of soft rays. Many intermediate positions and structures occur between the two examples here described, i.e., the dorsal fin may be only slightly notched, or it may be deeply indented, or when two fins are present they may be very close together or far apart. In some fish, as in the salmon, the second dorsal fin contains no rays and it is often referred to as a "flesh fin" but most authors call it the "adipose fin." The codfish, *Gadus callarias,* has three dorsal fins, and the mackerel, *Scomber scombrus,* in addition to two normally formed dorsal fins, has a series of small, detached finlets, posterior to the second dorsal, and another series posterior to the anal fin. In some fishes the dorsal fin is very long, extending from the head or shoulders to the caudal fin or it may even be united and continuous with the caudal fin, as in the conger eel, *Leptocephalus conger.*

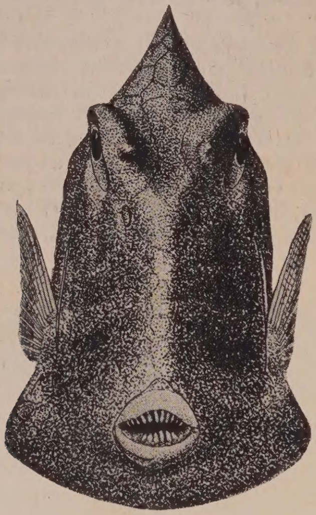

Fig. 68.—Trunkfish, *Lactophrys tricornis.*

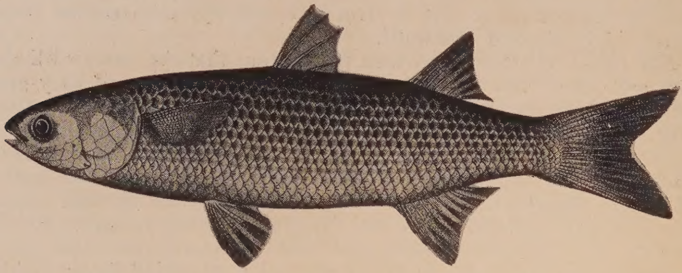

Fig. 69.—Striped Mullet, *Mugil cephalus.*

A very common form of the caudal fin is that found in the shad, *Alosa sapidissima,* in which species the tail fin is forked, consisting of an upper and a lower lobe. In the spotted weakfish, *Cynoscion nebulosus,* and many other species, the posterior margin of the caudal fin is slightly concave to nearly straight, and in nearly all of the flat fishes, as well as in many other forms, it has a rounded margin. A wide variation from the more usual forms of the caudal fin, already described, may be seen in comparing with them the tail of the thresher shark, *Alopias vulpes,* which has an immensely long upper lobe, equaling fully half the total length of the beast.

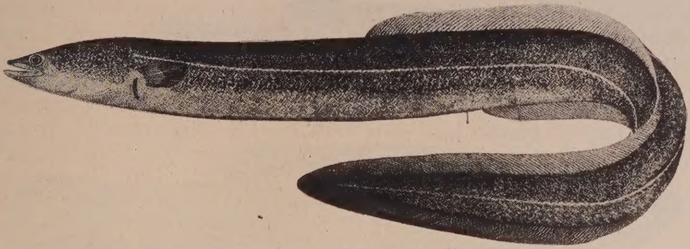

FIG. 70.—Conger eel, *Leptocephalus conger.*

The anal fin usually is single, but there are a few exceptions, as for example in the cod, *Gadus callarias,* which has two anal fins, and rather rarely this fin is entirely wanting, as in most skates and rays. The common and well known sawfish, *Pristis pectinatus,* much feared, although quite harmless to man, has no anal fin. In the greatly depressed species, such as the rays, which lie and move about and feed very close to the bottom, an anal fin projecting downward from the body would indeed be a hindrance, to say nothing of the abuses which such an organ would suffer under the mode of life led by these animals. In shape and form the anal fin is subject to nearly as much variation as the dorsal fins. A peculiarity about the anal fin in some fishes, as in the viviparous top minnows, is its connection with sex. In *Gambusia,* for example, the rays

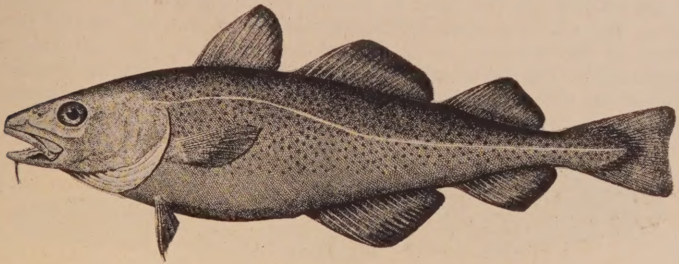

FIG. 71.—Cod, *Gadus callarias.*

in the adult male are united, and the fin is long and prong-shaped. This fin serves as an intromittent organ for conveying the "male element," sperms, from the male to the female.

The ventral fins, too, occasionally are wanting. The eels or apodal fishes, for example, have no ventral fins. The shape and size of the ventral fins are subject to the usual great variation among species; the range in position or place of insertion, is particularly great. In some fishes these fins are inserted under the head, as for example in the eelpout, *Zoarces anguillaris,* when they are said to be "jugular." In other species they are attached to the chest or thorax, as in the sea bass, *Centropristes striatus,* and they are then called "thoracic." When the ventral fins are inserted on the abdomen, as in the salmon and trout, they are said to be "abdominal." The designation of the position of the ventral fins is very useful in the classification of fishes. The ventral fins in most sharks and in some of the skates and rays bear a direct relation to sex, as the so called "claspers" of the male, used in copulation in those species in which the eggs are fertilized internally, are attached to the ventral fins.

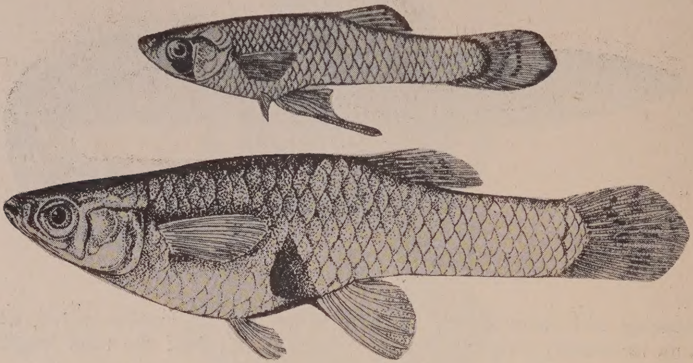

Fig. 72.—The top minnow, *Gambusia holbrooki.*
Upper—male.
Lower—female.

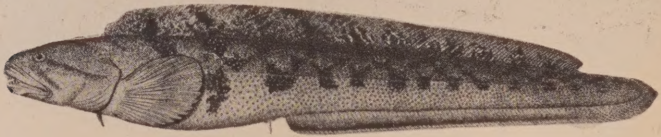

Fig. 73.—Eelpout, *Zoarces anguillaris.*

The pectoral fins are perhaps more variable in shape than the ventral fins but rather less variable in position, as they are always attached somewhere to the shoulder girdle. They may be inserted high up on the side of the fish or they may be placed at or near the ventral edge. The difference in size is great, varying from very small, rudimentary or even wanting, as in some of the soles, to large and spreading as in the skates and rays, and elongate and wing-like, as in the flying-fishes.

Regeneration of Fins.—The "limbs" or fins of fishes, unlike those of higher vertebrates, when broken or bitten off (or cut off for the sake of an experiment) regenerate. The newly formed part or parts do not always look exactly like the original fin and they may frequently be distinguished from the normal organ. A remarkable case of regeneration in a pipe-fish, *Doryamphus lineatus,* was once observed by the author. This fish evidently had lost a part of its tail, as the usual number of segments were wanting, but a somewhat dwarfed and twisted caudal fin had been regenerated on the last caudal segment present.

Function of Fins.—It is probable that the caudal fin is the principal organ used in propelling the body, the other fins, together with the swim bladder, serving mainly in balancing and guiding the fish. A remarkable departure from the usual function of the fins is found in the flying-fishes, some of which are able, because of the long wing-like pectorals, to "fly" above the surface of the water for distances upward of a hundred feet. The pectoral fins, however, cannot be used as in birds. The motive power is the action under water of the strong tail and no force is acquired while the fish is in the air. The long, broad pectoral fins merely aid the fish, after it has made its strong leap from the water, to stay in the air somewhat longer, exactly as the quiet expanded wings of a bird keep it from falling to earth as rapidly as it would with folded wings.

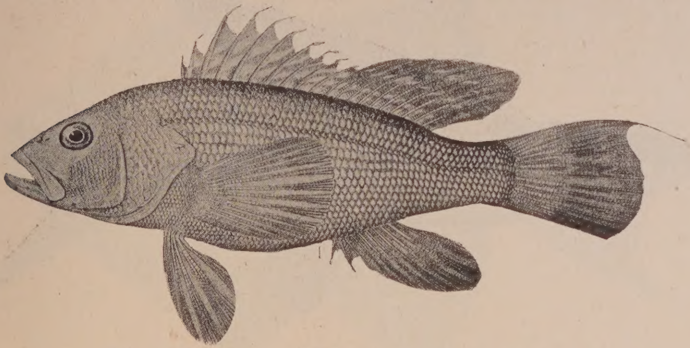

FIG. 74.—Sea bass or blackfish, *Centropristes striatus.*

The Mouth.—The shape, size and position of the mouth in fishes are all subject to remarkable variations. The most usual form is a terminal (to slightly inferior or slightly superior) mouth of moderate size. Among the common food fishes having this type of mouth may be mentioned the shad, *Alosa sapidissima,* the steel-head trout, *Salmo gairdneri,* the striped mullet, *Mugil cephalus,* the Spanish mackerel, *Scomberomorus maculatus,* the striped bass, *Roccus lineatus,* the mangrove snapper, *Lutianus griseus,* the squeteague, *Cynoscion regalis,* and many, many others. A departure from the usual, or more normal, type of mouth, especially with respect to size, is found in the barracudas which have very large mouths and strong jaws. Other examples of extremely large mouths are found in the marine gars, or hound fishes, which have a greatly produced snout, usually two or more times the length of the rest of the head, with the cleft of the mouth reaching from the apex of the snout nearly or quite to the eyes. The opposite extreme, namely, the very small mouth is found in the pipe fishes, *Syngnathus*. In these fishes the very small mouth, which resembles a mere opening in a tube, is situated on the end of the greatly produced snout.

The inferior mouth is much less common than the terminal mouth, but it is not rare. This type of mouth is present in the sturgeons and in most of the sharks and skates and in some other fishes. The inferior mouth is correlated with bottom feeding, as most of the forms having the mouth in this position, feed largely at or near the floor of the water which they inhabit. An extreme type of the inferior mouth and projecting snout is found in the saw-fishes. In these animals the snout or "saw," bearing the "saw-teeth," is equal to two or more times the length of the rest of the head.

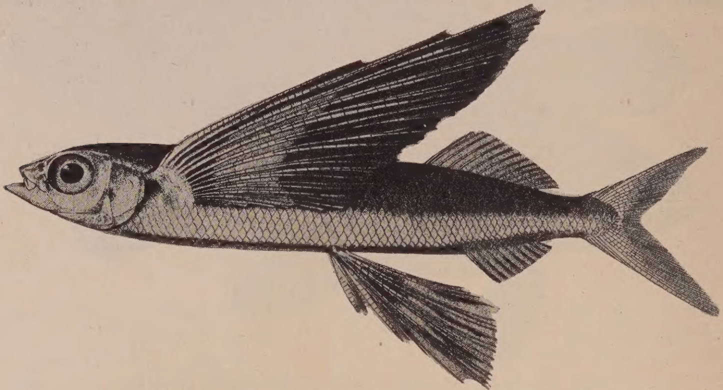

FIG. 75.—The flying fish, *Exocœtus volitans*.

The superior mouth with a projecting lower jaw occurs less frequently among fishes than the two types already described. The superior and oblique or vertical mouth is present in certain tropical sciænoid fishes of the Pacific Coast, as for example, in *Larimus argenteus*, and *Nebris occidentalis* and also in the Atlantic Coast electric toadfish or star-gazer, *Astroscopus y-græcum*. An example of a superior, but horizontal, mouth occurs in the remoras or shark suckers and a very extreme type of a greatly projecting lower jaw is found in the half-beaks, in which the projecting lower jaw greatly exceeds the length of the rest of the head.

The Teeth.—The teeth in fishes, regardless of the size, shape and position of the mouth, vary greatly, each species being provided with the type of teeth needed (or rarely no teeth) for the kind of food it eats. Thus, among the fishes having mouths of moderate size and terminal, or nearly so, the snappers, for example, being predatory, and living largely upon other fishes, have rather strong and sharply pointed teeth. The mullets, *Mugil,* which feed largely upon diatoms and other microscopic organisms, therefore having little need for teeth for grasping or crushing, are provided with very small, weak teeth. The shad, *Alosa sapidissima,* which also feeds mainly upon minute organisms, has small, weak jaw teeth when young which, however, are lost with age. The trigger fishes, *Balistes,* in proportion to their size, have immensely large teeth. A specimen of *Balistes naufragium,* 22 inches in length, has teeth not unlike in size to those of man. They are strong and, although notched, they resemble the incisors in the human jaw. It was learned by the writer, through a painful experience, that these teeth can be used very effectively for cutting, and it is not doubted that they also are effective for crushing. The opposite extreme, as to size and number of teeth in fish, is found in the spade-fishes, *Chætodipterus.* In these fishes the teeth are very numerous, slender, close-set and brush-like and, instead of being rigid and attached to the bone, they are movable. The teeth in the parrot fishes, *Scaridæ,* represent another extreme type. The jaw teeth in these fishes are fused, forming a continuous cutting edge, resembling the beak of a bird.

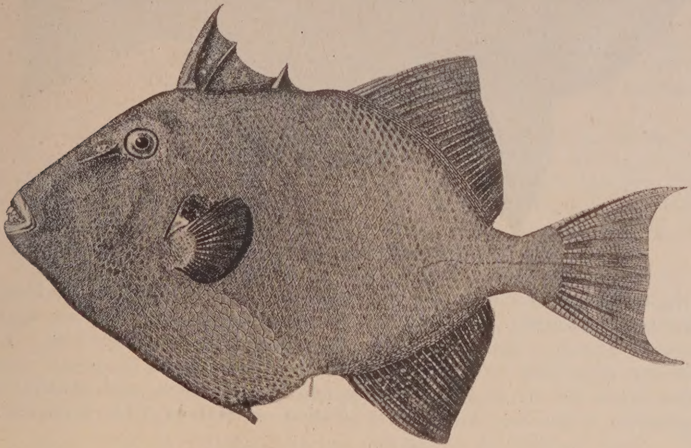

FIG. 76.—The triggerfish, *Balistes carolinensis.*

The majority of the sharks and skates have comparatively large and formidable teeth which, however, vary greatly among species. The teeth in these cartilaginous fishes are not set in the bone (cartilage) as in most teleosts, but are merely attached to the "gums." A common type of tooth occurring in sharks is that found in the blue shark, *Carcharinus milberti.* The teeth in this species are flat, triangular, with broad bases, and sharply serrated cutting edges and with the free apex either erect or directed inward and backward. Such teeth obviously are suitable for grasping and cutting. Very different teeth are found in some of the skates and rays, as, for example, in the devil-fish, or eagle ray, *Aëtobatus nari-*

nari. This ray has very low and wide teeth, each tooth being provided with a broad surface. Teeth of this kind evidently are intended for crushing hard objects and the species, provided with this type of dentition, subsist principally upon mollusks and crustaceans.

Some fish, in addition to the teeth on the jaws, have teeth on the bones of the roof of the mouth, i.e., on the vomer and palatines, and sometimes on the tongue, as for example, the amber-fish, *Seriola,* and in the bluefish, *Pomatomus saltatrix* and others. Another rather odd but not unusual position of teeth in fishes is on the pharyngeal bones in the throat. These teeth are especially well developed in the black drum, *Pogonias cromis,* in the oyster-fish or tautog, *Tautoga onitis,* and others, and usually serve as grinders of foods. The oddest location of teeth in fishes occurs in the butterfishes, *Stromateidæ,* which have lateral sacs developed in the œsophagus in which hooked teeth are present.

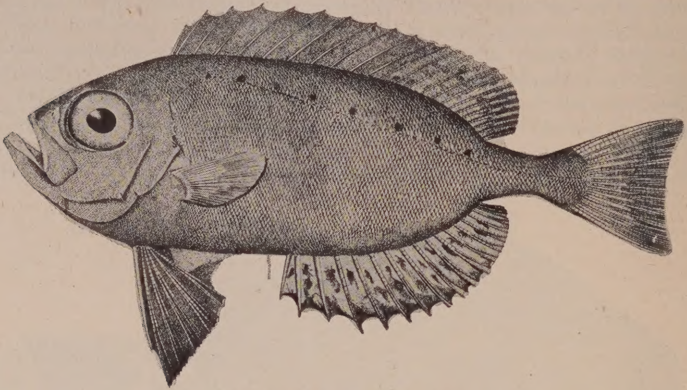

FIG. 77.—The catalufas, *Priacanthus arenatus.*

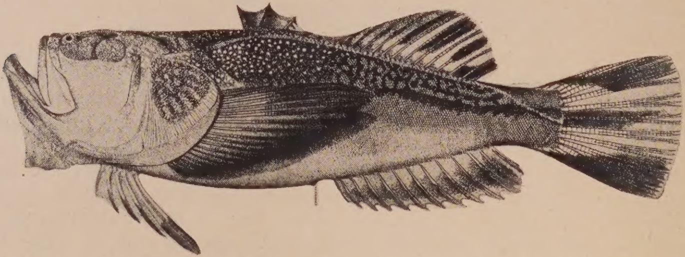

FIG. 78.—Electric star gazer, *Astroscopus y-græcum.*

The Eye.—The variations in the size of the eye are quite as remarkable as the differences in the size of the mouth. The position of the eye, however, always is lateral to superior, never inferior or directed away from the light. An example of an extremely large eye occurs in the catalufas, *Priacanthidæ*. A specimen of *Priacanthus arenatus*, 11 inches long, for example, has an eye approximately 1⅛ inches in diameter. The electric star-gazer, *Astroscopus y-græcum*, on the other hand, has an eye which is a mere dot placed on the dorsal surface of the head.

The accuracy of sight in fishes and the range in which the eyes function are generally not well understood. It, however, is doubtful that vision in fishes is highly developed. The author, who has made a special study of the top minnows and particularly of *Gambusia*, has found that these fish cannot see mosquito larvæ, one of their principal foods, at a distance exceeding approximately 3 inches, and, furthermore, that these fish are unable, at any and all distances, to distinguish between a mosquito larva and small bits of stick, as long as the immature mosquito remains perfectly quiet. It is only when the larva "wiggles" within about three inches of the fish that it is recognized as food.

Sight in fishes appears to be developed only to the extent that it is needed under the environment in which they live and for the particular life they lead. Thus certain cave dwelling species which live in the dark constantly have completely lost the sense of sight.

The Ear.—Fish have no external ear but they have an inner ear which consists of a chamber, lying very close to the brain, in which are found the ear-stones or "otoliths." It is quite certain that most fish can "hear," but hearing probably consists merely of detecting disturbances in the water, possibly aided in some fish by certain sense organs, located in the *lateral line*, to which reference again will be made.

The Nostrils.—The nostrils in fish are pits in the snout and they do not communicate with the throat, as in the higher vertebrates, but each nostril has one or two exterior openings. It has been definitely determined that some fish are able to detect odors but, as is the case with respect to the eyes and ears, the extent to which the nostrils function independently of the other senses is still very imperfectly understood.

The Lateral Line.—Most fishes have a line along the side, extending in most cases from the head to the tail, known as the "lateral line." Tubes are located in the lateral line and behind these are numerous nerves. The exact function of the lateral line organs is not well known. It has been variously supposed that they aided the sense of taste, hearing and smell. Most recent authors believe they aid the sense of hearing and assist the fish in detecting disturbances in the water, thus enabling it to avoid enemies. Many of our common food fishes, however, have no lateral line. Among the fishes having no lateral line are the shads, the alewives, the herrings, the sardines and the mullets.

Tactile Organs.—Many fishes possess special organs of touch, which serve in exploring the bottom or of feeling their way to their food. In the catfishes, croaker, black drum, goatfishes, and many others these organs consist of barbles which are long in some species and short in others, and they may be attached at the nostrils, to the maxillary, at the chin, to the rami of the lower jaw, to the skin of the snout, etc. They vary in number from one, as in the cod, to many, as in the black drum.

The tactile organs in some fish consist of modified fins, as for example in the cusk eel, *Rissola marginata*, in which the ventral fins assume the shape of long slender "feelers," or they may be constituted of detached rays as in the thread-fins, *Polynemidæ,* the gunards, *Triglidæ,* and various other fishes. Barbles or fleshy flaps are also often developed over the eyes, along the lateral line, on the scales or on the fins.

The Gills.—It was stated in a preceding paragraph that fishes live in the water and that they breathe by means of gills. These organs, therefore, function in the fish as lungs do in air breathing vertebrates. The gills are situated behind the mouth cavity and they consist of bony arches to which are attached reddish fringes. Each fringe is provided with a small blood vessel and as the water passes through the mouth or through the "spiracle" (a hole behind the eye), as in some sharks and skates and rays, it passes over these fringes. The water is then brought very close to the blood and the oxygen in the water is absorbed through the very thin walls of the gill-fringes and at the same time the impurities, or body wastes, in the blood pass out into the water. The final result is clearly identical with that accomplished in the lungs of air breathing animals.

Nearly all of our common food fishes have four pairs of gill-arches, and those of one side all open into one so-called "branchial chamber," having a common opening. The branchial chamber is well protected by a bony shield, the "gill-cover." The sharks (with a few exceptions) and the skates and rays, on the other hand, have five separate external gill-openings, known as "gill-slits."

Many fish, in addition to the filaments attached to the gill-arches, already described, have the anterior-inner edge of the bony arch, particularly the first arch of the series, provided with teeth or bristles. These projections are "gill-rakers," which are variously developed and in some fishes wanting. The pelagic species, like the menhaden, *Brevoortia tyrannus,* for example, have long close-set and very numerous gill-rakers which are used in screening from the water minute organisms upon which they feed. In other fish in which the gill-rakers are not needed in acquiring food, they probably serve the purpose of arresting foreign matter which otherwise might clog the gills.

The Air-Bladder.—The air-bladder or swim-bladder in fishes lies in the abdominal cavity and close to the dorsal wall, when present, and it is in a measure comparable to the lungs in higher vertebrates. When "lungs" are developed in fishes, as they are for example in a rudimentary way in the fresh water gars, *Lepidosteus,* they consist of a modified air-bladder. The functions of the air-bladder have been variously estimated. It, however, is doubtful that this organ has any value as a lung in fishes, which respire by the aid of gills, but its chief use no doubt is to serve the fish as an organ of equilibrium, aiding the animal in rising and sinking in the water. It is rather significant that many of our bottom dwelling fishes, the flat-fishes for example, in the adult stage at least, do not have an air-bladder. This organ also is absent in sharks, skates and rays.

The air-bladder also is associated with the "voice" in fishes. The voice, however, consists of little more than grunting or croaking sounds. The voice is especially well developed in the croaker, *Micropogon undulatus.* The grunting or croaking of this fish may be heard for a considerable distance below the surface when one of these fish is caught on a hook, and it is also produced after the fish is taken from the water.

The Alimentary Canal.—The alimentary canal in fishes may be long or short. It may consist of a simple stomach and an almost straight intestine, its total length being shorter than the body. The short and simple alimentary canal is usually associated with the carnivorous species, but the herbivorous fishes more frequently have the stomach provided with blind sacs or "cœca" and a long, convoluted intestine. Certain fishes, like the mullets, *Mugil,* have a very heavy muscular stomach, resembling the gizzard of a chicken. The sharks and skates and rays, and a few fresh water forms, have "leaves" in the intestine, forming what is known as the "spiral valve." The functions of the peculiar structures of the alimentary canal in the various species cannot be discussed here, farther than to remark that each fish has been provided with the particular type of digestive organs needed for the food upon which it feeds. In general, as already stated, the fishes with a short alimentary canal are carnivorous and those with a long, coiled alimentary canal are herbaceous.

The Color.

The colors in fishes vary greatly. Some species are of a modest uniform color, others are variegated and of brilliant coloration. Nearly all fishes are darker above than below, many of them being pale or white underneath. An exception to this general rule is presented by the remoras or shark-suckers which usually are lighter on the back than on the belly. These fish commonly attach themselves to larger fish, or other creatures, by means of a sucking disk situated on the dorsal surface of the head, and in that way they are propelled about without effort on their own part. They usually attach themselves in such a way that the belly is up or toward the light. This habit of being "towed" about, in the manner described, very probably accounts for the reversal of the usual coloration in fishes.

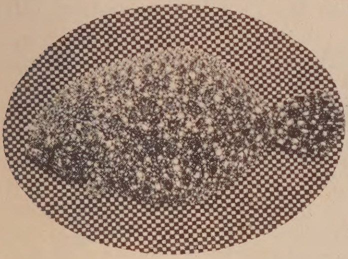

FIG. 79.—The southern flounder, *Paralichthys albiguttus,* on a background of black and white squares, showing color simulation.

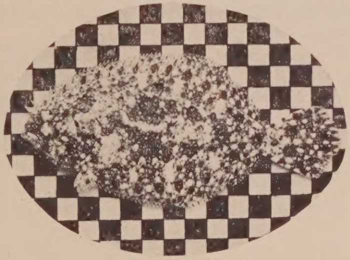

FIG. 80.—The southern flounder, *Paralichthys albiguttus,* on a background of large black and white squares showing color simulation.

The most brilliantly colored fishes are found in tropical seas and principally among the inhabitants of the coral reefs. Many fishes undoubtedly bear protective colors but it is improbable that the bright colors found among the labrid and parrot fishes and others can serve such a purpose. It, on the other hand, has been stated by divers that the bright markings harmonize remarkably, and are comparatively inconspicuous in the water among sea fans, corals and other bottom growths. Examples of protective coloration, however, are evident everywhere. The flounders which lie close to the ground imitate the bottom upon which they happen to be. They become pale, with indications of darker markings, when they are on white sand; when they are on coarser material, such as crushed shells, the markings are larger; and when they lie on dark or black ground they change to a dark color. Mast,[1] in making a study of the changes in color and pattern of the flounders, *Paralichthys*, was able to produce in the fish nearly all the colors of the spectrum by placing them on variously colored back-grounds, such as sand, shells, granite-ware pans, white back-ground with round black spots of various sizes, etc., etc. In each case the flounders to a surprising degree simulated the color and pattern of the background upon which they were resting.

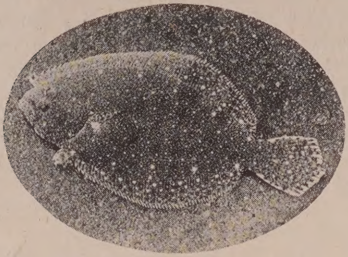

Fig. 81.—The southern flounder, *Paralichthys albiguttus,* over sand, showing color simulation.

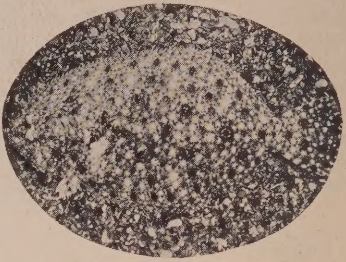

Fig. 82.—The southern flounder, *Paralichthys albiguttus,* on shells, showing color simulation.

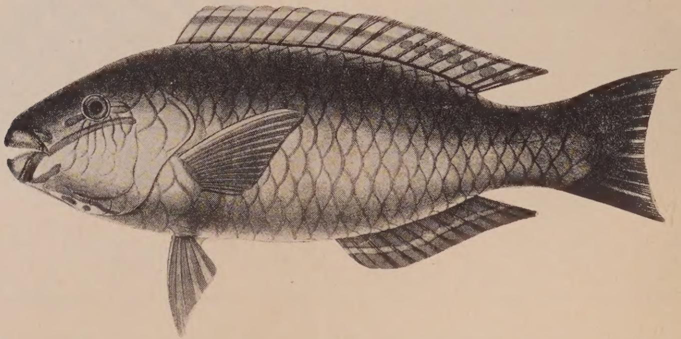

Fig. 83.—The parrot fish, *Sparisoma trocheli.*

The sexes sometimes are differently colored, although such differences are less common than among birds. Such striking contrast exists in color of the sexes of certain species of the brightly colored labrid and parrot fishes of the tropical waters that the opposite sexes in a few instances, at least, have been described as separate and distinct species. Nuptial or breeding colors, which appear on the male during the breeding season, are not unusual among our fresh water fishes but they are rather rare among marine forms.

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[1] *Bureau Fisheries, Bull. 34* (1914), 175-238.

It is entirely impossible to explain the purpose, if indeed they serve any purpose, of some of the markings of fishes, as already indicated in the case of the brilliantly colored fishes of the tropical coral reefs. Certain special markings have been grouped by authors under the head "recognition marks" and it has been supposed that they might serve a given species in recognizing the individuals of that species. Whether or not such markings as red, blue, black, yellow or green spots, ocelli, bars of various shapes and colors, and the like, serve the purpose of recognition among individuals of a species, they do serve as recognition marks to the fisherman and the naturalist.

The Foods.

The foods upon which fishes subsist vary greatly among the various forms, as already shown by the description of the remarkable differences in the structure of the mouth, teeth, gill-rakers and alimentary canal, these organs all being adapted to the food required by the different species. The general type of food utilized by any particular fish may often be determined from a study of these characters, but it is usually much more difficult to ascertain the particular animals or plants upon which a species subsists. This difficulty arises from the fact that, first, many fishes like the shad, alewives and others feed upon copepoda and similar minute organisms which are taken more or less continuously, but in rather small quantities and it is rather rare that a large quantity of these organisms is present in the stomach at one time. Even when found, recourse to the microscope must be taken to make identifications. Secondly, many fishes appear to have very rapid digestion. It, at least, is unusual to find newly caught foods in some of the rapid swimming pelagic species, such as the mackerels. The third reason for the difficulty of determining what a fish recently has eaten, is the well known habit of throw-up the last meal, when hooked or taken in a net.

Some species, as for example the cod, are omnivorous, eating nearly any kind of food of suitable size, and taking it anywhere between the surface and the bottom. Others are rather restricted in their foods, being strictly carnivorous or herbivorous, feeding mainly on one or two classes or groups of animals or plants. Thus the black drum, *Pogonias cromis,* is a bottom feeder and subsists very largely upon mollusks and crustaceans. The rudder fishes, *Kyphosus,* on the other hand, feed mainly on plants, green algæ being the principal food. Still other fishes feed only on small or minute organisms, as already stated. Some of these fishes feed at the surface, as for example the menhaden, and they strain their food from the water by means of many and numerous gill-rakers. Still others, which feed upon similar minute organisms, are able to extract their food largely from mud and ooze, stirred up and gathered from the bottom.

While many comparatively large fishes obtain sustenance from microscopic organisms, others take huge forms in proportion to their size. For example, the writer some years ago took a fresh and brackish water goby, *Eleotris picta,* 14½ inches in length, which had swallowed another goby, *Philypnus maculatus,* 8½ inches long. The head of this "morsel" was near the vent and largely digested while the tail was still visible in the mouth. It is, furthermore, of record that certain fishes, at times, have swallowed other fishes exceeding their own length.

It has been shown in the preceding paragraphs that some fishes feed on other fishes and also that others feed upon lower animals. The question naturally follows, What do the lower animals feed upon? It may be said at once, without going into details, that creatures may prey upon other creatures, but it is a well known fact that the original source of food consists of plants, and in the final result they depend upon the vegetable kingdom. This interlocking and intimate relationship, with respect to foods, between the various groups of animals and finally their dependence upon plants, has frequently been overlooked, or at least insufficiently considered, in determining the effects of pollutions. Fishermen, as a rule, have been content in believing that no damage was resulting from pollutions unless they actually found dead fish. It, however, is evident that if a break occurs anywhere in the "chain" supplying foods for any particular species that this fish will migrate, if it can, to more favorable feeding grounds. It must also be remembered in this connection that young fish or fry usually depend upon different foods than the adults of the same species. It, therefore, is entirely possible that the adults may be able to acquire sufficient foods in a locality where the food for the fry may be wanting. Since most fishes when hatched, and for some time afterwards, are very small and nearly or quite translucent, it would indeed be a difficult task to detect the dead, even if they occurred in large numbers. It, then, is evident that pollutions may affect our fisheries adversely to a much greater extent than is generally supposed and, also, that the study involved is a complex one.

Migrations.

Nearly all fishes migrate more or less, some species traveling only short distances and others going on long "cruises." Migrations appear to depend principally upon three causes or conditions, namely, the development of the breeding organs, the need of food and the season of the year or the temperature of the water. Most fishes have customary breeding grounds to which they migrate from year to year to deposit their eggs. The most readily observed example of migrations for the purpose of spawning occurs in the anadromous fishes which mature in the sea and ascend fresh water streams only for the purpose of depositing their spawn. Among the American species of anadromous fishes are the salmon, the shad, alewives, sturgeons and the striped bass. Some fishes migrate to deeper water for the purpose of spawning and others go to shallower water. The general movements of the cod, *Gadus callarias,* is to shallower water during the breeding season, although it probably does not come as close to the shore as was once supposed. The common eel, *Anguilla rostrata,* on the other hand, reverses the migration of the anadromous species, as it leaves the fresh waters and runs out to sea, to deep water, to spawn. Fishes which leave the fresh waters and go to the sea to spawn are called "catadromous" species. Many species, of course, do not make special migrations for the purpose of reproduction but deposit their eggs in suitable places on or near their customary feeding grounds.

Migrations, for the purpose of seeking foods, probably are made to a certain extent by all fishes, but the species which go in schools, such as the mackerels, for example, "travel" more or less constantly and they go long distances in search of food or in the pursuit of their prey. It can readily be seen that schooling fish necessarily have to cover a larger area in search of food than the solitary species, as the supply in any one place must be quickly exhausted when numerous fish, all feeding on the same animals or plants, concentrate there. The solitary species, on the other hand, usually can find foods in one place for a much longer time.

Migrations brought about by the season of the year, or temperature, are so closely connected with migrations for foods that no clear distinctions can be made. It is true that the majority of our shore fishes go to deeper water and, therefore, warmer water, during cold weather, but such a migration may be only in part for the sake of escaping from low temperatures. Another reason for seeking the deeper holes probably is for the purpose of finding foods. The menhaden, *Brevoortia tyrannus,* regularly makes long migrations northward during the spring and southward during the fall. It again is an open question whether those migrations are undertaken for the purpose of remaining in water of a certain temperature or for the purpose of finding the proper foods or both.

It is not surprising, in view of the large extent of the watery home of marine fishes, that the majority of them wander considerable distances, either along the shores, to and from deeper water off shore, or in rare cases perhaps across oceans. In many cases the direction and the purpose of these movements are very imperfectly understood.

Geographical Distribution.

It is much more difficult to determine the exact geographical distribution of fishes than to determine the range of most land animals whose courses or trails can be seen and followed. It often is easy for a fish to swim on and on in the broad seas without hindrance and it is rather a wonder that more marine fishes are not of cosmopolitan distribution.

The geographical range of fishes in general appears to be limited by three factors, first, individuals have been unable to reach certain regions because of the presence of barriers of some sort. The most common barriers, hindering wider distribution, are land, water temperatures and, for some species, shallow water and, for others, deep water. It may be stated, in explanation, that that which may form a barrier for one form, may aid another in extending its range. A deep water fish, for example, would be aided by an extension of deep water but shallow water would limit its range. The opposite condition holds true for shallow shore forms, for they would perish in deep water almost as certainly as on land. Second, a species after having reached a certain locality may not be able to maintain itself because of a change in environment to which it cannot adapt itself or because of competition with other forms. Third, a species may be able to maintain itself and multiply but because of the change in environment in the process of adaptation it may undergo such changes that it becomes a species distinct from the original type.

A fine illustration of changes brought about through a change in environment is found in fishes on the opposite coasts of Panama. All geological and biological evidence overwhelmingly favors the existence of a natural inter-oceanic waterway across the Isthmus, in comparatively recent times, through which fish could pass from ocean to ocean. Some of the species, since the close of this passageway, have yielded more rapidly to the change in environment than others. A comparatively small number are still so nearly identical that they cannot be separated by the systematist. The majority are separable by small, but constant, and by no means trivial differences. The change in characters, which has taken place, many times consists only in a small difference in the number of gill-rakers present, or a similar small difference in the number of scales in a lateral series. Other differences are noticed in the number and size of the serrations or spines on the opercle, preopercle, and scales; a slight difference in the depth of the body; the size of the eye, etc., etc.

Cases of irregular distribution are not entirely uncommon, the supply of foods being in most cases responsible. The menhaden, for example, was scarce on the coast of North Carolina for several years previous to 1917, but in that year the usual abundant fall run reappeared. The tilefish, *Lopholatilus chamælenticeps,* at one time abundant off the shores of our north Atlantic states, suddenly disappeared, probably due to a heavy mortality, and several years later it reappeared in commercial abundance.

Spawning and Reproduction.

All fishes have definite breeding or spawning seasons. This season varies among species, but it occurs during the spring or early summer in the majority of fishes. Among the important commercial species which, however, spawn at other seasons of the year may be mentioned the Atlantic salmon, most of the salmon of the Pacific Coast, the menhaden, the striped mullet, the cod, winter flounder, and the spot of the Atlantic Coast, all of which spawn during the fall or winter.

Many fishes have definite spawning grounds, as well as breeding seasons. The spawning grounds, which for many species also are feeding grounds for the early stages of the young fish, are extremely important. Our knowledge concerning the exact location of the spawning grounds of many commercial species is still far from complete. It is very evident that before intelligent legislation, looking toward the protection and conservation of any species, can be undertaken, such information must be at hand. It has been pointed out on a preceding page that some species migrate toward the shore or into streams to spawn, but a more usual movement perhaps is off shore to deeper water. The squeteague, *Cynoscion regalis,* for example, enters shallow water and particularly the estuaries of streams early in the spring and it remains there until the roe is nearly ripe, when it migrates to deeper and larger waters. Later the "spent fish" return to reoccupy the feeding grounds in the shallow water.

Most fish lay eggs which are fertilized usually at the moment they are laid, and no further attention is given them by the parents. In some species the eggs, however, are protected, as for example in the pipe fishes. In these fishes the eggs are transferred from the female to the male, who fertilizes and carries them in a sort of pouch, situated on the ventral surface of the body, until they are hatched. In some of the marine catfishes the male carries the eggs in the cavity of the mouth until they are hatched, and the young for some time after they are hatched.

In certain forms, as in some skates and rays, the eggs are fertilized internally and laid afterwards. The egg cases of skates and rays are known to every one living on the seashore. The shell is hard and more or less four-cornered, each corner being provided with stiff rods or tendrils. In some of our brackish and fresh water minnows, *Gambusia, Heterandria* and *Mollienesia,* the eggs are fertilized and hatched internally and the young are born alive. This also takes place in certain perches of the Pacific slope. No placenta, however, is present in these so-called "viviparous" species. The only difference between these fish and the egg laying species or "oviparous" species, is the internal fertilization and hatching of the eggs. In some sharks and rays a sort of placenta is developed and among these lower forms of fishes we find the nearest approach in the process of reproduction to that taking place in mammals. No care, however, is taken of the young, after they are born, by these fish parents. Most fishes have two ovaries, but some of the elongate, slender forms, such as the needle- or hound-fishes, *Tylosurus,* have a single ovary.

Fish eggs may roughly be divided into two groups, viz., demersal and pelagic. Demersal eggs are heavier than the water in which they are spawned and they are either deposited on the bottom, or they sink after being laid. The herrings are among the important commercial species which produce demersal eggs. The cod, on the other hand, produce pelagic or floating eggs. It is obvious that the floating eggs may be widely dispersed by tides, winds and currents before they are hatched, and the feeding grounds of the young fish, therefore, are much greater in extent than they are among the young hatched from demersal eggs. The demersal eggs and the young hatched therefrom are in much more danger of being destroyed by fishing operations, as for example in trawling, but since the young are hatched approximately in the same place where the eggs are laid the proper foods for the fry are much more apt to be present than where the fry from the drifting eggs happen to be hatched.

The eggs of fishes differ greatly in size and form among the species. The horny egg cases of certain skates already have been mentioned. In most of the higher fishes the eggs are spherical and large or small according to species. The anchovies, however, produce ovate eggs. The eggs of the silversides bear adhesive gelatinous threads by means of which they become attached to submerged objects. The marine catfishes produce large eggs, those of *Felichthys felis* being approximately an inch in diameter. The eggs of the common eel, on the other hand, are said to be so small that they are almost microscopic.

Fish may have comparatively few, or they may have numerous eggs. As a rule those species with large ova produce fewer eggs than those with small ova. The marine catfish, *Felichthys felis,* appears to spawn not over

55 eggs at one time. The red salmon, *Oncorhynchus nerka,* according to Jordan, has only about 3,500 eggs. The cod, on the other hand, according to Günther, may spawn over 9,000,000 eggs during a single season.

The time required in hatching varies greatly among the eggs of different species, as well as with respect to temperature. Large eggs, as a rule, take longer to hatch than small eggs. The eggs of the scallop-fish, *Ctenogobius stigmaticus,* for example, which are so small that they are scarcely visible with the unaided eye, have been hatched in about 18 hours, while the average length of the period of incubation in salmon, which have relatively large eggs, exceeds a month. It is said that in the case of salmon eggs an allowance of about 5 days' difference in the length of the incubation period must be made for every degree of change in the water temperature.

Larval Development.

The larval and postlarval forms of fishes all differ more or less in shape and form from the adult. In certain forms, as for example in the eels, *Anguilla,* the larva differs from the adult nearly as much as the caterpillar differs from the butterfly. The young eel or *Leptocephalus* is flat, ribbon-shaped and nearly transparent. The mouth is provided with long, sharp, fang-like teeth. The young eel, in the process of metamorphosis, actually undergoes a distinct shortening of the body. Most young fish when first hatched do not possess definite fins, but merely "fin folds." They are usually almost colorless and they have a very large head and proportionately large eyes. Even in, and after, the postlarval stage fishes differ considerably from the full-grown form. The young horsehead, *Selene vomer,* for example, has a much less vertical anterior profile than the adult. It has long filaments on the spinous dorsal and the ventral fins are very long, but the anterior rays of the second dorsal and the anal fin are not produced. The adult, on the other hand, has a comparatively low spinous dorsal, short ventral fins and with greatly produced rays in the anterior part of the second dorsal and the anal fins. The young mullets, *Mugil,* for a long time were considered a separate and distinct genus under the name *Querimana.* They differ from the adult principally in being of a much brighter and more silvery color and in having two instead of three anal spines. The color gradually changes and when the fish has reached a length of approximately two and one-half inches it conforms mainly with that of the adult. During this time the first soft ray of the anal fin is transformed into a spine. Marked changes in the structure of the mouth, teeth, gill-rakers and the alimentary canal take place in many species during the postlarval stages. The last named changes often can be accounted for as provisions for the accommodation of a different diet, but the purpose served by other changes mentioned are more difficult to explain.

Effects of Fishing.

The possibility of the total extermination of any species of marine fish is perhaps much more remote than the extermination of some of the large land animals, but it is evident that a gradual diminution of several important species is taking place. In some cases species, previously important, have ceased to be of commercial value. The question naturally arises: What can be done to conserve and protect our marine fishes? It was indicated on a preceding page, that our knowledge of the habits and life history of our marine fishes is still far too meager to deal intelligently with this problem, but it is evident that measures of some kind are necessary. One of the most effective regulations, when it can be applied, is a closed season during the spawning period of a given species. The prohibition of dragging nets over spawning grounds of fishes producing demersal eggs and the setting of higher limits of the smallest fish which may be taken are other measures worthy of consideration. Furthermore, conservation can be attained by utilizing species which are now little, or not at all, used for food.

The Geographical and Vertical Distribution of Some Important Commercial Fishes of the United States.

Most of our common marine food fishes live near the shores, or they at least come near the shores at certain seasons. Many enter harbors, bays and inlets. Others enter estuaries of streams and some of them ascend rivers. Still others rarely, if ever, come close to the shore, but they occupy banks or deeper and colder, or warmer, water, as the case may be, off shore. It was shown on the preceding page that some fishes constantly occupy deep water; also that some species live and feed close to the bottom. Others usually are found at or near the surface. The bottom dwelling species are usually referred to as "bottom-feeders" or "ground fish," and those that habitually occur at or near the surface are called "pelagic fishes." Other fishes indiscriminately occupy the surface or the bottom, or any depth between the two, of the water which they inhabit. Still another group, known as the "anadromous" fishes, i.e., fishes which enter fresh water streams to spawn, cannot at this time be classed with either of the foregoing groups, because of the lack of definite knowledge concerning their movements in the sea.

Among the common commercial fishes of the Atlantic seas border which inhabit shallow shore waters and live at or near the bottom are several species of flounders, or flat fishes, including the winter flounder, *Pseudopleuronectes americanus,* the sand dab, *Lophopsetta maculata,* both of northern distribution, ranging from the middle Atlantic states northward. Among the flat fishes also occur the summer flounder, *Paralichthys dentatus,* and the southern flounder, *Paralichthys albiguttus,* which are of more southern distribution, occurring principally from Chesapeake Bay southward. Another very common and abundant ground-feeder is the croaker, *Micropogon undulatus,* which is taken in large quantities from Chesapeake Bay southward. The whitings, also known in some localities as "kingfish," "sea mink," and "sea mullet," belong to the bottom feeding fish. Three species are included among the whitings of the Atlantic Coast, namely, *Menticirrhus americanus, M. littoralis,* both taken from the middle Atlantic states southward, and *M. saxatilis,* which is caught principally from Chesapeake Bay northward. All the whitings are choice food fishes.

The black drum, *Pogonias cromis,* a fish reaching a large size, but with flesh of inferior flavor, also is a bottom-feeder. It is found in commercial abundance from the middle Atlantic states southward. The tautog, also known as "blackfish" and "oyster fish," *Tautoga onitis,* ranging from New Brunswick to South Carolina, may be grouped with the bottom dwellers. The sheepshead, *Archosargus probatocephalus,* a valuable food fish living principally among rocks, and ranging from Massachusetts southward, also belongs to this group of bottom feeders.

Among the common commercial species of pelagic, or surface feeding and swimming, fishes which inhabit, or at least periodically visit, the Atlantic Coast of the United States are several mackerels. The common mackerel, *Scomber scombrus,* which is taken from the middle Atlantic states northward, is the most important species of the mackerel family. The Spanish mackerel, *Scomberomorus maculatus,* is of southern distribution, being taken principally from Chesapeake Bay southward. The kingfish, also known as "cero," *Scomberomorus cavalla,* is common only on the southern parts of the Atlantic Coast of the United States. The mackerels are all choice food fishes and of considerable commercial importance. The common herring, or sea herring, *Clupea harengus,* which commercially is one of the most valuable of all American food fishes, also belongs to the pelagic fishes. It occurs in the northern Atlantic, on both coasts, and in America it is taken principally north of Cape Cod. Another member of the herring family which is also a surface swimming species and of great commercial importance, although sparingly used as food for man, is the menhaden, *Brevoortia tyrannus.* This fish is one of the most abundant of all ocean fishes and its range extends along the entire Atlantic and Gulf coasts. The products manufactured from this fish are oil, fertilizer, and fish meal. The bluefish, *Pomatomus saltatrix,* a choice food fish of great commercial importance, is perhaps less pelagic in its habits than some of the other species mentioned, yet it is properly placed in this group. It is caught along the entire Atlantic and also along the Gulf Coast of the United States. The swordfish, *Xiphias gladius,* generally remaining some distance off shore, also belongs to the pelagic species. It reaches a very large size, the average weight being 400 to 500 pounds, and it is of wide distribution, occurring on both sides of the Atlantic and also

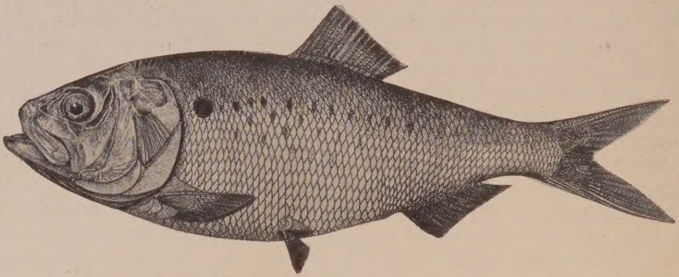

FIG. 84.—Menhaden, *Brevoortia tyrannus.*

in the Pacific. It is the subject of special fisheries off the shores of the north Atlantic states.

A large number of important commercial fishes, occurring on the Atlantic Coast of the United States, cannot be classed either as bottom or surface feeding or dwelling species. Among them occur the weakfishes or squeteagues, *Cynoscion regalis,* and *C. nebulosus.* Both species are caught in large quantities on the coasts of the middle Atlantic states. The former is taken in abundance from thence northward and the latter from there southward. The spot, *Leiostomus xanthurus,* ranging from Massachusetts southward, also belongs to these shore fishes which cannot be grouped either as surface or bottom feeders. Other species belonging to this general group are the butter-fishes, *Poronotus triacanthus,* taken in abundance from Massachusetts to North Carolina, and *Peprilus alepidotus,* more frequently known as "harvest fish," taken chiefly from Chesapeake Bay southward. The scup, *Stenotomus chrysops,* taken in abundance from Massachusetts to Chesapeake Bay, may also be grouped here. The porgee, *Chætodipterus faber,* and the snappers, grunts and groupers, all of which occur chiefly on the coasts of the southern states, also fall into this group.

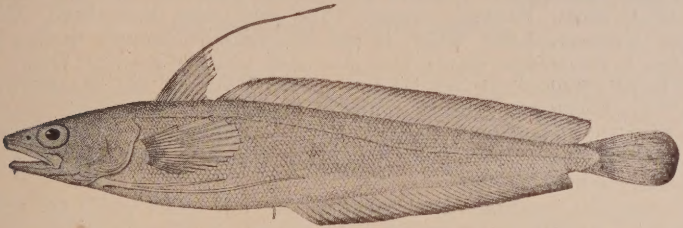

FIG. 85.—The hake, *Urophycis chuss.*

The mullets, *Mugil cephalus* and *M. curema,* which are taken on the Atlantic Coast from Massachusetts southward, may be said to belong both to the bottom and surface dwellers, as they are either on the bottom stirring up the soft ooze or they swim and skip about at the surface, frequently making leaps into the air.

Among the common commercial fishes which live chiefly at some distance from the shore and in rather deep water, the following species may be mentioned: Cod, *Gadus callarias,* the haddock, *Melanogrammus æglefinus,* the hakes, consisting chiefly of two species, *Urophycis tenuis* and *U. chuss,* the silver hake, *Merluccius bilinearis,* the cusk, *Brosme brosme,* the sea bass or blackfish, *Centropristis striatus,* the halibut, *Hippoglossus hippoglossus,* and the tilefish, *Lopholatilus chamæleonticeps.* All of these species, with the exception of the sea bass, which ranges from Maine to Florida, are taken in commercial numbers only off the coasts of the north Atlantic and New England states.

The common anadromous fishes of the Atlantic Coast consist of the smelt, *Osmerus mordax,* taken chiefly in New England, the alewives, including two species, *Pomolobus pseudoharengus,* also known as the "branch herring," and *P. æstivalis,* known as the "glut herring," which are caught principally in the rivers of the middle Atlantic states. The shad, *Alosa sapidissima,* one of the most valuable of all American food fishes, ascends all suitable fresh water streams along the Atlantic border from the St. Johns River, Florida, northward. The striped bass or rockfish, *Roccus lineatus,* and the white perch, *Morone americana,* are important food fishes from North Carolina northward to New England. One other anadromous species, the Atlantic salmon, *Salmo salar,* formerly much more common than now, may be mentioned among this group of fishes. It enters all suitable rivers north of Cape Cod and it formerly extended southward to the Hudson River. The sturgeon, *Acipenser sturio,* which enters rivers from South Carolina northward, too, belongs to this group, but its numbers are being depleted and its commercial importance is declining.

Among the common shore fishes of the Gulf Coast which live at or near the bottom may be mentioned the flounders, *Paralichthys lethostigmus* and *P. albiguttus,* which are taken on the coasts of all of the Gulf states. The croaker, *Micropogon undulatus,* too, occurs in commercial abundance along the entire Gulf Coast. Another ground fish, taken in large quantities, is the black drum, *Pogonias cromis.* The salt water sheepshead, *Archosargus probatocephalus,* which is also essentially a bottom feeding fish, is taken in commercial numbers on the coasts of all of the Gulf states.

The principal pelagic species on the Gulf Coast are the Spanish mackerel, *Scomberomorus maculatus,* and the menhaden, *Brevoortia tyrannus.* The bluefish, *Pomatomus saltatrix,* taken in commercial abundance principally on the coast east of the Mississippi River, too, may be mentioned as belonging to this group.

Among the important food fishes of the Gulf Coast which are neither bottom nor surface swimmers are the groupers, snappers (exclusive of the red snapper) and the grunts, each consisting of two or more species. These species are caught principally on the west coast of Florida. The southern squeteague, *Cynoscion nothus,* and the red drum or redfish, *Sciænops ocellatus,* taken in large quantities along the entire Gulf Coast, too, belongs to this group of shore fishes. The crevalles, cavalley, hard tails, or blue runners, *Caranx hippos* and *C. crysos,* taken mainly on the western coast of Florida, are placed here, although they probably just as properly might be placed with the pelagic species.

The mullets, *Mugil cephalus* and *M. curema,* which, as already stated, are either surface or bottom swimmers, are by far the most important commercial species taken on the Gulf Coast. They are taken in commercial abundance from Florida to Texas.

The only off shore species of the Gulf, which is taken in large quantities, is the red snapper, *Lutianus blackfordi.* The fish caught for market are from one to three feet in length and several million pounds are taken annually and shipped to many parts of the United States.

The common commercial species of fishes inhabiting the waters of the Pacific Coast include several species of flounders, some of which are strictly shore fishes, occupying shallow water, others live in water of moderate depths and still others remain constantly in deep water. Some of the flounders of the Pacific Coast are marketed under the name "soles." The flat fishes, as a whole, are taken in large quantities along the entire sea border of the Pacific states. The rockfishes, composed of a number of species variously known as "black rockfish," "brown rockfish," "green rockfish," "orange rockfish," "red rockfish," etc., etc., principally living among rocks in shallow or moderately deep water, also may be placed among the ground species. Rockfishes are taken on the coasts of all of the Pacific states.

Among the pelagic species of the Pacific Coast may be mentioned the sardine, *Sardina cœrula,* taken along the entire sea border; a fish now ranking as one of first importance. Another species of great commercial value, belonging to this group, is the albacore, *Germo alalunga,* which is canned and popularly known as "tuna." The albacore reaches a large size and is taken in commercial abundance only on the coast of California. The Pacific herring, *Clupea pallasii,* is abundant on the coast southward to San Diego Bay from December to April.

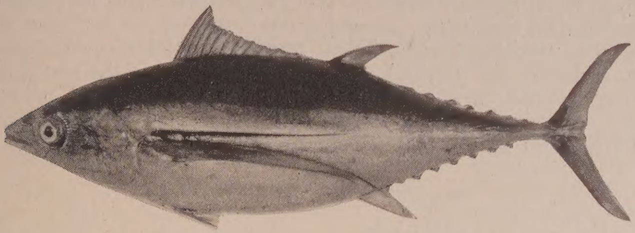

FIG. 86.—Albacore, *Germo alalunga.*

The barracuda, *Barracuda argentea,* and the yellowtail, *Seriola dorsalis,* are species which reach a large size. They are not strictly pelagic and are taken in commercial numbers only on the coast of southern California. The sea bass, *Cynoscion nobilis,* too, reaches a large size. It is even less pelagic in its habits than the two preceding species. This important fish ranges from Puget Sound southward, but it is taken chiefly on the coast of California.

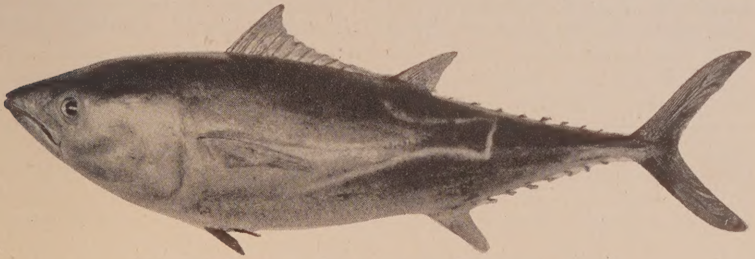

FIG. 87.—Horse mackerel or tuna, *Thunnus thynnus.*

Valuable off shore species, in the Pacific, are the halibut, *Hippoglossus hippoglossus,* found southward to Monterey, California. This halibut, as already indicated, is the same species which occurs off the north Atlantic

Coast of the United States. The arrow-toothed halibut, *Atheresthes stomias,* taken from San Francisco northward, may also be grouped as an off shore, deep water species. The Pacific cod, *Gadus macrocephalus,* taken from Oregon northward, and the lingcod, *Ophiodon elongatus,* taken along the entire Pacific Coast of the United States, also belong to the off shore fishes.

Among the important anadromous fishes of the Pacific Coast are two species introduced from the Atlantic, namely, the shad, *Alosa sapidissima,* now taken in all suitable rivers on the Pacific Coast, and the striped bass, *Roccus lineatus,* caught in commercial numbers only on the coast of California. The steel-head trout, *Salmo gairdneri,* and the various species of salmon, including the blueback, the chinook, the chum, the humpback and the silver salmon, are exceedingly important commercial anadromous species. Millions of pounds of these fish are marketed annually, partly in the fresh and partly in the canned state.

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Chapter 12

The Importance of the Fisheries.

By LEWIS RADCLIFFE*

THE value of the annual harvest of fish and fishery products approximates $800,000,000, and subsequent increase in value resulting from manufacturing raises this total to more than one billion dollars. The important fisheries of the world lie almost wholly within the north temperate zone, for the most part crowded between the fortieth and sixtieth parallels of north latitude. Except along the northern fringe (particularly in the Bering Sea district) the fisheries of this belt are prosecuted with vigor and their potential yield and extent are reasonably well known.

On the whole, the fisheries of the tropics are unimportant and hold forth little promise of offering serious competition with those of the temperate regions. Although less is known of the character and extent of the fisheries of the south temperate zone, it can be stated with assurance that they are incapable of supplying the vast quantities obtained in north temperate waters.

The all-impelling desideratum in the life of a fish, except as abated at the reproductive period, is food. The massed land areas in the north temperate zone with their extensive lake and river systems pouring their living flood into the sea, the extensive coastal indentations and large continental shelves, with relatively shallow water, banks and island groups, and the ocean waters of these sections teeming with their unsurpassed supply of fish food—microscopic and macroscopic—supply the foundation for an extensive and continuing fish life, incomparable with tropic, south temperate or polar waters. As an illustration of this concentration, the fisheries of the following countries—the United States, Great Britain, Japan, France, Spain, Canada, Norway, and Russia—represent at least 70 per cent in value of the total yield.

The total catch of these countries approximates 12,000,000,000 pounds annually, of which about 20 per cent is credited to the United States. The catch of Japan is believed to be not much if any smaller; that of Great Britain is about 1,800,000,000 pounds; Norway, 1,600,000,000 pounds; Russia, 1,200,000,000 pounds, and France, Spain and Canada between 850 and 900 million pounds each.

Among the important world fisheries are those for herring, salmon, the gadoid fishes (cod, haddock, hake, pollack, etc.), the mackerel and mackerel-like fishes (including the tunas), and the shellfish fisheries, the chief of which is the oyster.

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In productiveness none exceed those of the herring family, numbering more than 150 species, distributed over the greater part of the earth, in both salt and fresh water, which contribute more to the support of the human race than any other family of fishes. These furnish the raw materials for the highly important sardine industries of France, Spain, Portugal, Norway and the United States, the extensive herring curing industries of northern Europe and North America and the most important sources of raw materials for the valuable fish scrap, meal and oil industries of the United States, Norway and Japan, more than 1,000,000,000 pounds being used each year in the by-products industries alone.

The cod, haddock and other gadoid fishes, of which there are about 140 species, are of importance chiefly in the north temperate zone between the fortieth and sixtieth parallels of north latitude. Those of the north Atlantic and adjacent seas have long contributed a vast annual harvest to the peoples bordering thereon. Those of the north Pacific appear capable of much greater development than in the past. These fishes are marketed largely in the fresh state and preserved by salting, both dry salted and pickled.

The salmons, confined almost exclusively to the same belt, are noteworthy for their food qualities, size, beauty, and gameness. The family, *Salmonidæ,* includes the whitefishes, ciscoes or lake herring and trouts as well as the salmons. Some live in fresh-water lakes and streams, while others are marine and anadromous. The most important members of the family are the five species of salmon belonging to the genus *Oncorhynchus* which abound in the north Pacific, entering the tributary rivers in North America and Asia to spawn. The fisheries are distributed along the coastal region of California, Oregon, Washington, British Columbia, Alaska, Siberia and Japan. Upon reaching maturity, these species approach the coast and ascend the rivers to spawn. It is during this migration that the fisheries are most vigorously prosecuted. After spawning the parent fish die and the young upon reaching maturity return to the parent stream to spawn.

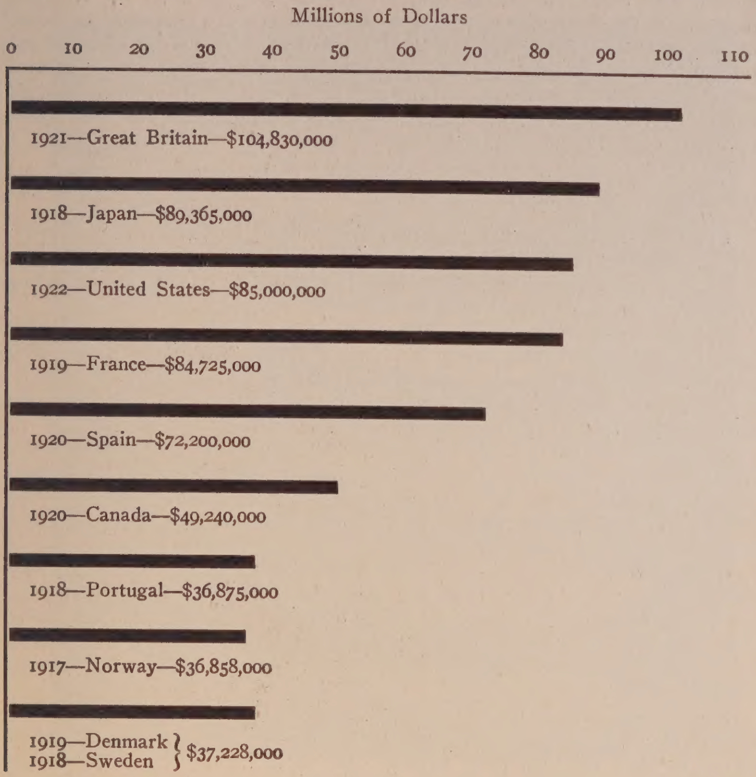
The mackerels, of which there are about 60 species, like the herrings, are widely distributed, and some are among the most cosmopolitan in character. They are highly prized for food, fresh, salted and canned, and support important industries in countries where they are taken in abundance.

The shellfish fisheries are not so widely distributed, the oyster fisheries being of importance, chiefly in the United States, France and Japan. The pearl oyster fisheries are also of considerable importance in India, the Philippines and other localities.

Importance of the Fisheries.

Next to agriculture, the fisheries are the most important source of human food. In point of value, the following countries are among the most important in making use of this valuable protein food: Great Britain, Japan, United States, France, Spain, Portugal and Norway. The comparative value of the fisheries of these countries, including those of Denmark and Sweden, representing about 75% of the total value of the world's fisheries, are shown in the following table.

Comparative Value of the Catch of the Chief Fish-Producing Countries



Fisheries of the United States.

From the very beginning of our history our fisheries were of the greatest importance, some of the early settlements, at times, being wholly dependent for continued existence upon fish, the only available food supply. Their importance as a source of food and for the training of seamen for war or peace-time pursuits have served to maintain a high place for them in our industrial growth. At the present time there are about 180,000 persons actively engaged in the fisheries of the United States and Alaska. The total investment amounting to approximately $170,000,000 includes nearly 6,000 vessels of 5 tons net or over; more than 60,000 power, sail and row boats and fishery apparatus valued at about $15,000,000. The annual yield of fishery products exceeds 2,500,000,000 pounds, with a value of $85,000,000 to the fishermen and a much greater value as prepared for market. Of the total catch, about 68 per cent consists of marine products, 20 per cent of anadromous species such as the salmon, shad and river herring which leave the sea and enter the rivers to spawn and 12 per cent of fresh-water forms. The Atlantic seaboard supplies about 64 per cent of the catch; Alaska, the Pacific Coast states and the interior United States waters about 12 per cent each. Actual published statistics, some of which date back to 1908, will disclose some variation from these percentages, but for all practical purposes these represent a close approximation.

Fisheries by Groups.

For convenience our fisheries may be grouped into classes as follows: (1) sea fisheries including bank and pelagic fisheries; (2) coastal fisheries including marine and anadromous; and (3) fresh-water fisheries including the fisheries of the Great Lakes and interior waters.

Sea Fisheries.—Our most important fishing areas are the relatively shoal water banks (bank fisheries) lying off the eastern coast of North America from Newfoundland to Massachusetts. These banks are about 70,000 square miles in area, and support highly important fisheries for cod, haddock, halibut, pollack, hake, and other fishes.

On the west coast, from Oregon to Alaska, there are fishing banks, which maintain important fisheries for halibut, cod, sablefish and other species. In addition to these localized bank fisheries, there are important fisheries for such pelagic species as mackerel, bluefish, swordfish, etc., of a more cosmopolitan character.

Coastal Fisheries.—These include the fisheries prosecuted along our extensive coast line, in the bays and other indentations for marine coastal species such as squeteague, croakers, flounders, mullet, tautog, crabs, clams, lobsters, oysters, scallops, shrimp, and other fish and shellfish, as well as the fisheries for anadromous species (salmon, shad, river herring or alewives, etc.).

Fresh-Water Fisheries.—The fisheries of the Great Lakes are the most important of our fresh waters, the more valuable species being whitefish, ciscoes or lake herring, pike, perches and carp. Our river fisheries for buffalofish, carp, catfish, sturgeon, sunfish and fresh-water mussels are of considerable local importance.

The More Important Fisheries.

Salmon.—The salmon fisheries of the Pacific Coast states and Alaska easily outrank others in value. The annual catch averages 475,000,000 pounds. In 1918, the domestic catch was about 614,000,000 pounds, the manufactured products including more than 387,000,000 pounds of canned salmon and 7,800,000 pounds of pickled, mild-cured and dry salted, while in excess of 30,000,000 pounds were marketed fresh or frozen. In that year the salmon fisheries of Alaska gave employment to 28,000 persons, the investment exceeded $66,500,000 and the value of the products was $53,500,000.

The five species of commercial importance are as follows: Chinook or king, the most highly prized of the salmons but of less importance than the red salmon because of its lesser abundance; flesh, deep salmon, red to white. It is marketed chiefly in the canned, mild-cured, frozen and kippered form. Red or sockeye salmon, the most important commercially, is in especial demand for canning and pickling. The flesh is red, firm, of good texture and the canned product is exceeded in price only by the Columbia river chinook.

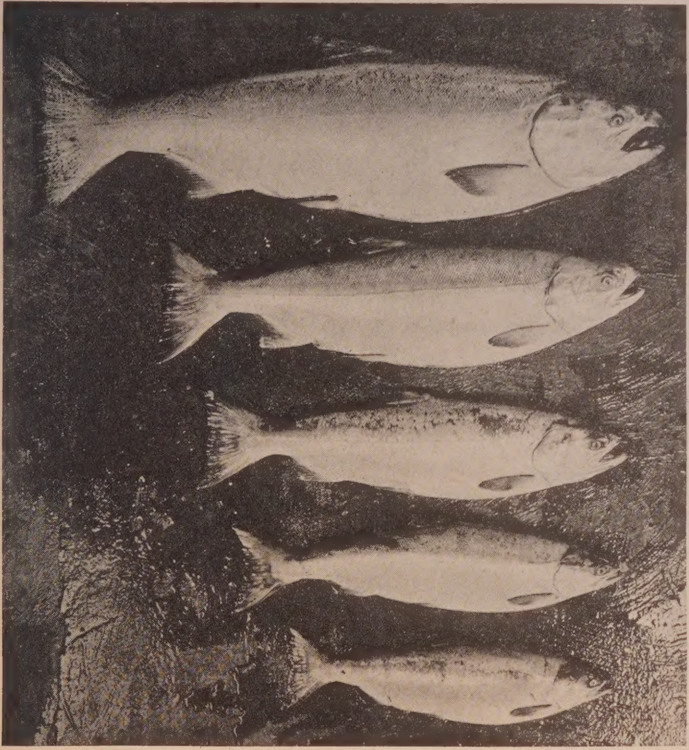


FIG. 88.—The five Pacific salmons of the *genus Oncorhynchus.* Uppermost, king; dog; silver; sockeye; humpback.

Silver or coho salmon is rated as inferior to the chinook or red for canning, but superior to the pink or chum. Its flesh lacks the clear red color of the more highly prized species and is known to the trade as "medium red." It is also used in the fresh and frozen and mild-cured and pickling industries.

Pink or humpback salmon is chiefly used for canning, being of minor importance in the fresh and pickled salmon industries. The flesh is pale pink and less firm, being classed as one of the cheaper grades.

Chum or keta salmon is used principally for canning. The flesh is rather soft, yellowish in color and therefore in less demand by those who are accustomed to judge quality by color.

In addition to these the steelhead trout is usually classed with the salmons by the trade. It is of importance in the fresh and frozen salmon trade and small quantities are canned.

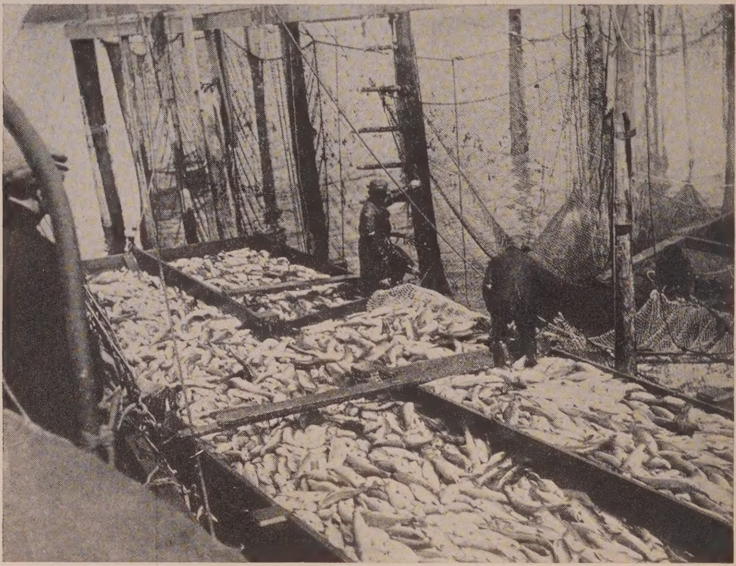


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FIG. 89.—One of two scow loads of 18,000 salmon each taken in this trap in one day.

Until recently, the United States produced in excess of 80 per cent of the world's production of canned salmon. With the rapid growth of the Siberian canning industry, developed largely by the Japanese, we now produce only about 73 per cent.

Oysters.—This fishery is noteworthy along the Atlantic seaboard from Rhode Island to Louisiana. The present annual yield amounts to about 150,000,000 pounds, valued at about $15,000,000 to the fisherman. Oysters are marketed fresh and canned, the pack of canned oysters being valued at about $2,000,000. The shells are ground and used as grit for poultry or lime for the soil to counteract acidity. In 1921, nearly 260,000 tons with a value of $2,260,000 were produced. The catch of oysters in Maryland and Virginia in 1920 was 8,511,040 bushels with a value of $4,640,081. The oyster fisheries of the Pacific states are relatively unimportant.

Herring.—The principal herring fisheries of the United States are located in Maine, California and Alaska. The catch of sea herring in Maine, amounting to in excess of 100,000,000 pounds annually, is the basis for the important sardine canning industry. The pack in 1922 amounted to 1,775,878 cases valued at $5,750,109, as compared with 2,450,268 cases valued at $11,933,986 in 1919. The adult sea herring are extensively used in the smoked fish trade.

In California, a pilchard scarcely to be distinguished from the pilchard of Europe is used for canning as sardines. The pack in 1922 amounted to 728,979 cases, valued at $3,361,480 as compared with 1,150,616 cases in 1919. Exports of canned sardines in 1922 exceeded 20,000,000 pounds. The Alaska sea herring is highly valuable for curing by the Scotch method, being considered by the trade as one of the best if not the best species for curing by this method. These fisheries also yield considerable quantities of fish fertilizer, meal, and oil.

The menhaden, a member of the herring family occurring along our entire Atlantic Coast, is used almost wholly for the production of fish scrap for fertilizer, fish meal for feeding hogs, cattle, and poultry, and fish oil used in the manufacture of soap, paints, etc. The annual catch of this species varies from 600,000,000 to 900,000,000 pounds. Thus the total annual catch of members of the herring family ranges from 800,000,000 to in excess of 1,000,000,000 pounds and the value of the products from $8,000,000 to in excess of $15,000,000.

Cod.—The annual catch of cod exceeds 100,000,000 pounds and is marketed fresh, salted, and dried. The principal fisheries lie off the New England and the Canadian coasts, chiefly on the fishing banks. In addition, several million pounds are taken on the banks off the coast of Alaska each year.

Haddock.—The annual catch of haddock, which is landed almost entirely at New England fishing ports, amounts to about 90,000,000 pounds and is marketed fresh, salted, and dried or smoked. Recently an important business has been built up in marketing the fresh fish, filleted and wrapped in parchment paper. This method of treatment promises to mark an epoch in the fish business in increasing the market and helping to solve the question of production, which can be greatly increased.

Halibut.—The annual catch of halibut amounts to about 60,000,000 pounds, the bulk of which is marketed fresh or frozen and represents one of our most highly prized fishes. With the partial depletion of this fishery on our Atlantic Coast banks, operations were largely transferred to the west coast, chiefly to the banks off Alaska, and in recent years the bulk of the catch has been obtained from this region.

Among our other important fisheries are those for ciscoes or lake herring in the Great Lakes district, with an annual yield in excess of 50,000,000 pounds; alewives or river herring, along the Atlantic seaboard, yield about 45,000,000 pounds; squeteagues or sea trout, Atlantic Coast south of Cape Cod, annual catch in excess of 40,000,000 pounds; shrimp taken in the south Atlantic and Gulf States, California, and Alaska, annual catch exceeding 40,000,000 pounds; crabs, taken principally in the Middle

Atlantic States section, yield exceeding 30,000,000 pounds; and shad, native to the Atlantic Coast and transplanted to the Pacific Coast, yield about 27,000,000 pounds.

Imports and Exports.

The import and export trade of the United States in fish and fishery products is important. In 1919 the value of such imports was $35,760,712 as compared with $35,151,155 in 1920 and $29,041,707 in 1921. Our export trade for these years was as follows: 1919, $48,023,698; 1920, $31,498,507; and 1921, $15,950,430.

Exports.—Following is a summary of exports in 1921:

	Pounds	Value
Fresh, except salmon	11,430,769	$ 904,737
Dried, smoked, or cured—		
Cod, haddock, hake and pollack	18,482,227	1,752,393
Herring	4,574,960	261,077
All other	1,163,087	104,939
Pickled, except salmon	18,017	216,172
Salmon—		
Canned	50,498,411	7,508,253
Pickled	5,884,400	1,398,993
All other salmon	....	443,277
Canned fish, except salmon and shellfish	....	1,635,572
Shellfish—		
Oysters	....	591,698
All other	....	831,488
All other fish and fish products	....	301,561
Total fish		$15,950,430

Exports of all fish in the fiscal year 1914 amounted to $12,842,173, of which salmon, chiefly canned and cured, constituted about 80 per cent and oysters 5 per cent. In 1920, exports were $31,498,507, of which salmon was less than half. Our exports of fresh fish have been relatively small. Exports of fresh fish, except salmon, in 1914 were 6,534,460 pounds, valued at $366,871, most of the shipments going to Canada and Cuba. Exports of fresh fish in 1920 approximated 10,000,000 pounds valued at about $900,000.

Imports.—Imports for consumption in 1920 were 262,671,266 pounds, valued in foreign markets at $34,122,423. Of this total, shellfish (chiefly crab meat from Japan and lobster from Canada) constituted $6,345,233. Cured or preserved fish amounted to 168,723,182 pounds, valued at $17,241,478, consisting largely of cod, haddock, hake, and pollack, chiefly from Canada and Newfoundland; sardines, chiefly from Norway, Portugal and France; herring and mackerel, chiefly from the United Kingdom, Canada, Newfoundland, and Holland. Fresh fish, exclusive of shellfish, amounted to 113,174,345 pounds, valued at $10,535,712, and were received mostly from Canada. The bulk of the imported salmon, halibut, and smelt, are received in the fresh state; most of the imported cod, haddock, hake and pollack are cured or preserved, and the herring and mackerel are pickled or salted.

Following is a summary of imports in 1921:

	Pounds	Value
Cured or Preserved Fish—		
Cod, haddock, hake, and pollack	55,257,759	$ 3,486,070
Fish (except shellfish) in oil	16,420,184	3,294,895
Herring	60,949,916	3,369,031
Mackerel	15,796,983	1,209,803
All other	17,634,911	2,487,122
Fresh fish—		
Halibut	24,252,250	3,172,923
Salmon	11,495,880	1,119,719
Smelts	7,003,819	910,491
All other	81,997,177	5,891,003
Shellfish—		
Crab meat	2,580,657	1,112,344
Lobsters—		
Canned	1,587,905	749,859
All other	9,469,641	1,441,614
Shrimp and other shellfish, and turtles	....	796,833
Total		$29,041,707

Fisheries of Canada.

Canada possesses one of the most extensive fisheries in the world. The Atlantic Coast line from Grand Manan to Labrador measures about 5,000 miles; that of the Pacific Provinces about 7,000 miles. In addition there are huge indentations of the sea, including the Gulf of St. Lawrence of some 80,000 square miles in extent, the Bay of Fundy with 8,000 square miles, Hudson Bay with a shore line of 6,000 miles and numerous interior lakes, which in the aggregate cover 220,000 square miles, Canada's share of the Great Lakes alone amounting to 72,700 square miles. In addition there are some 215,000 square miles of other ocean and coastal waters. Located in the north temperate zone, in the belt of heaviest fish production, it is not surprising that Canada's fisheries represent one of her most important natural resources, scarcely to be excelled by those of any other country within its natural boundary.

In 1918, Canada's fisheries were valued at $60,000,000; in 1919, at $56,508,479; in 1920, at $49,241,339, and in 1921, at $34,931,935. Low values in 1921 are due to the post-war depression and curtailment in production. In that year the value of the products of British Columbia, which leads the other provinces, was nearly $14,000,000, Nova Scotia ranking second with somewhat less than $10,000,000.

The important fisheries of the Atlantic Coast are those for cod, haddock, hake, and pollack (ground fish), mackerel, herring, smelts, lobsters and other shellfish. On the Pacific Coast the salmon, halibut, and herring are highly important. In interior waters there are valuable fisheries for whitefish, ciscoes, tullibee and other lake fish.

The catch of some of the more important species in 1921 was as follows: cod, 203,369,900 pounds; herring (including pilchards and sardines), 175,435,900 pounds; salmon, 87,592,300 pounds; lobsters, 39,362,500 pounds; halibut, 35,745,000 pounds; haddock, 26,922,200 pounds; mackerel, 14,554,400 pounds; pollack, 13,440,700 pounds; hake and cusk, 10,206,600 pounds.

Fishery Trade with the United States.—From 44 to 50 per cent or more of Canada's export trade in fish and fishery products go to the United States. Imports from the United States are less than an eighth of such exports and represent only 6 or 7 per cent of the entire export trade of the United States in fish and fishery products.

In 1921, Canada exported to the United States 121,337,100 pounds of fresh and frozen fish, valued at $9,438,539; 48,638,200 pounds of preserved products valued at $5,866,862, and miscellaneous products valued at $453,702, a total of more than 172,000,000 pounds valued at $15,759,103.

Canada is dependent on the United States for her market for fresh and frozen fish, from 90 to in excess of 99 per cent of her total exports of these commodities going to the United States. This country is also an important market for Canada's surplus of cured ground fish and for fresh and canned lobster. In 1921, exports of fresh and canned lobster to this country amounted to 8,140,500 pounds, valued at $3,264,131, which represents in excess of 20 per cent of the value of all fishery products exported to this country. These figures clearly indicate the extreme importance of the United States markets to Canadian producers.

Fisheries of the United Kingdom.

The fisheries of the United Kingdom are of exceeding importance to her population and the consumption of fish is unusually high, about 65 pounds per capita per annum. As in the case of the Japanese Island Empire, the domestic production of agricultural products and meats is relatively small. No point in either is far distant from the sea. A fare of fish landed at one of the English ports in the early morning may be in consumers' hands before nightfall. This is an exceedingly important factor in the distribution of so perishable a commodity as fish and accounts in part for the heavy consumption of fishery products.

In 1921, a year of depression and curtailed production of fish, the United Kingdom produced about 1,880,000,000 pounds of fish valued at in excess of $84,300,000, as compared with more than 2,400,000,000 pounds, with a value of about $106,000,000 in 1920. Production in 1920 was distributed as follows:

	Pounds	Value
England and Wales	1,633,454,256	$79,855,539
Scotland	708,505,168	24,254,194
Ireland	60,997,440	1,657,197
Total	2,402,956,864	$105,766,930

Note:—Quantity exclusive of shellfish, but value includes value of shellfish.

In 1921, the production of the following three species represented about 68 per cent of the total landings of fish:

Herring	610,410,192	pounds
Haddock	352,119,712	"
Cod	312,420,080	"

In addition to the catch by the British there were landed 144,757,648 pounds of fishery products from outside sources, chiefly from Norway. The large English markets, London and Liverpool, are world distributing centers for such fishery products as canned salmon and sardines. In excess of one-fifth of the world production of canned salmon is distributed through the markets of the United Kingdom each year, for home consumption and for reshipment.

Fisheries of Norway.

The fisheries of Norway are of the greatest importance to her, particularly for export to settle her balance for imports of grain, sugar, coffee, coal and the like. In 1913, of her production of more than 1,320,000,000 pounds of fish and fishery products, exports amounted to about 882,000,000 pounds. The more important items of export were canned fish, 68,342,000 pounds; stockfish, 59,524,200 pounds; salt cod, 125,662,200 pounds; salt herring, 185,186,400 pounds; other salt fish, 105,820,800 pounds; fresh herring, 178,572,600 pounds; other fresh fish, 15,432,200 pounds; herring scrap and meal, 52,910,400 pounds; fish and whale oil, 55,115,000 pounds; and cod-liver oil, 8,818,400 pounds.

Production of fish and fishery products in 1917 amounted to about 1,260,000,000 pounds valued at about $36,860,000. The catch of the more important species was as follows: cod, 224,895,000 pounds; other gadoids, 68,120,800 pounds; sea herring, 840,202,000 pounds; sprat or brisling, 20,229,220 pounds; coast mackerel, 34,302,400 pounds; salmon and trout, 15,448,400 pounds; lobster, 1,924,120 pounds; and miscellaneous fishes as halibut, flounders, eels, oysters, etc., 53,898,240 pounds.

In perhaps no other country has so much attention been given to the development of fisheries, including improvements in fishing gear and boats, preservation of nets and preservation of the products of the fisheries in a great variety of ways. Governmental assistance has been of the greatest benefit in accomplishing the highest development of the fishery resources.

Fisheries of Japan.

Despite Japan's small land area, she has a coast line of some 20,000 miles in extent well suited to marine industries. The fisheries have received much attention from private and governmental sources and are a highly important source of economic wealth to the Japanese. Whereas the American consumes about nine pounds of meat to one pound of fish, in Japan the ratio is reversed. The Japanese have given special attention to aquicultural farming including not only fish cultural operations but the growing of artificial pearls, of oysters, snapping turtles and the like on a commercial basis.

In 1918, approximately 1,400,000 persons were engaged in the Japanese fisheries, employing some 400,000 boats, and taking products to the value of about $89,000,000, as shown in the following table:

Value of marine products:

Fish	$64,306,500
Shellfish	4,028,500
Aquatic animals, etc.	10,429,500
Seaweeds	6,827,500
Total	$85,592,000

Value of aquicultural products:

Carp	$ 793,618
Eel	473,590
Oysters	383,345
Turtles, snapping	24,509
Algæ	1,392,132
Total	$ 3,067,194
Grand total	$88,659,194

The catch of the principal marine species in 1918 was as follows:

	Pounds	Value
Herring	655,129,420	$ 5,503,000
Sardine	565,352,620	8,564,000
Bonito	63,735,700	3,661,500
Cuttlefish and squid	92,340,600	3,727,000
Prawns	42,728,550	2,249,500
Mackerel	126,858,570	3,102,000
Tunny	27,660,800	2,171,500
Yellowtail	47,627,860	3,566,500
Tai (Porgy)	34,749,870	5,099,000
Total	1,656,183,990	$37,644,000

The principal forms of fishery apparatus employed by the Japanese are: otter trawl, purse seine, hand and trawl lines, haul seines, and gill nets. In the whale fisheries the modern whale gun is used to some extent.

Chapter 13.

Fishery Methods and Gear.

By LEWIS RADCLIFFE*

Our fishermen have an investment in fishery apparatus approximating $15,000,000. The life of a large part of this gear does not exceed two years, the fishermen investing about 8% of the proceeds of his annual harvest in new equipment. Increased effectiveness and radical improvement in such apparatus have long been discouraged rather than encouraged. Opposition arises chiefly from two sources, (1) from fishermen using less effective gear, and (2) through legislation enacted for the alleged purpose of conservation.

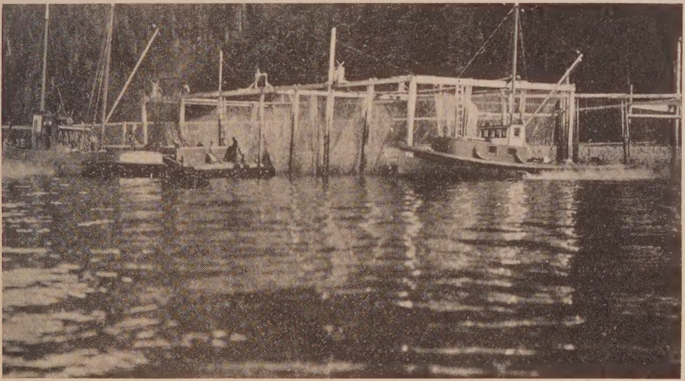

FIG. 90.—Pacific Coast salmon trap.

Here and there limits are placed on the use of such gear as pound nets or traps, purse seines, trawls, etc. These restrictions may apply to the construction of the net, such as size of mesh or as to seasons when its use is prohibited or its use prohibited altogether. In some instances an especially effective instrument of capture is so destructive as to warrant total prohibition, e.g., dynamite. Generally speaking, the encouragement to developing improvements and the adoption of new forms of gear has not been great.

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The visitor to our important Pacific salmon fisheries may compare the more primitive methods of capture employed by the aborigines, with some of the most modern and effective methods known. He may observe the lone Indian, laboriously dipping salmon, a fish or two at a time, from the turbulent river at his feet, and the fishing of a modern salmon trap, which has been known to yield 30,000 salmon, weighing in excess of 50 tons, at a single fishing. The salmon are removed from the trap with a large apron (brailer), operated by a mechanical hoist on the fishing tug, spilling its contents into large self-unloading scows. Between these extremes, there is an almost endless variety of gear, in use in the fisheries of the United States.

TABLE

FISHERY APPARATUS OF

Kinds	New England States, 1919		Middle Atlantic States, 1904 and 1920		South Atlantic States, 1918	
	Number	Value	Number	Value	Number	Value
Seines	441	$415,507	1,298	$292,120	673	$321,220
Gill nets	14,616	324,246	23,874	343,191	15,399	233,883
Trammel nets	—	—	5	533	—	—
Pound nets, trap nets, and weirs	1,119	1,087,997	3,527	1,586,209	3,779	355,439
Fyke nets	928	14,473	17,234	113,297	591	6,230
Stop nets	—	—	63	6,337	8	220
Hoop nets, pots and traps	—	—	—	—	—	—
Beam trawls	—	—	—	—	—	—
Otter trawls	492	37,987	2	220	371	22,055
Paranzella nets	—	—	—	—	—	—
Lampara nets	—	—	—	—	—	—
Wheels and slides	—	—	—	—	—	—
Lines	—	287,579	—	30,972	—	4,081
Eel pots and traps	4,239	7,341	17,953	18,545	1,585	1,329
Lobster pots	239,558	612,207	7,766	11,268	—	—
Crab traps, drags and pots	180	330	13	18	133	615
Crab dredges and scrapes	—	—	2,292	18,530	—	—
Dredges, tongs, rakes, etc.	7,176	47,955	25,974	232,737	2,865	11,406
Crowfoot grapples, rakes, etc.	—	—	—	—	—	—
Sponge apparatus	—	—	—	—	—	—
Whaling apparatus	—	29,000	—	—	—	—
Other apparatus	—	23,710	—	7,693	—	761
	—	$2,888,332	—	$2,661,670	—	$957,239

Of the total investment amounting to $15,000,000, about 42% is invested in pound nets, trap nets and weirs; 28% in gill nets; 12% in seines; 4% in lobster pots, and slightly more than 3% in lines, the five types mentioned representing 90% of the total investment. By sections this investment is distributed as follows: Atlantic seaboard, 46%; Pacific states and Alaska, 33%; and interior waters, 21%. As shown in the accompanying table, the three leading forms of apparatus—pound nets, gill nets, and seines—are also the most widely used, each appearing in every group of states shown, with the exception of pound nets in the Gulf States, where their use is prohibited. Of the more than 5,500 seines employed in our fisheries, the largest number or 23% are credited to the Middle Atlantic States. Of about 18,000 pound nets, trap nets and weirs, nearly 50% are used in the fresh-water fisheries of the Great Lakes and Mississippi Valley section, and of nearly 224,000 gill nets, about 68% are in use in the same section.

The number and value of the more important forms of fishing gear, by sections, are shown in Table 29.

29

THE UNITED STATES

Gulf States, 1918		Pacific Coast States, 1915		"Interior Waters," 1903		Alaska, 1921		Total	
Number	Value	Number	Value	Number	Value	Number	Value	Number	Value
825	$201,390	803	$343,180	1,263	$134,967	237	$168,894	5,540	$1,877,278
2,092	114,055	10,863	1,309,895	153,734	1,248,812	3,312	622,510	223,890	4,196,592
516	44,910	2,320	59,400	471	11,768	—	—	3,312	116,611
—	—	483	1,122,803	8,881	1,229,471	179	973,362	17,968	6,355,281
—	—	2,485	21,640	41,332	293,607	—	—	62,570	449,247
136	6,810	—	—	—	—	—	—	207	13,367
—	—	23,047	44,819	—	—	—	—	23,047	44,819
—	—	30	2,215	—	—	7	2,620	37	4,835
422	13,755	—	—	—	—	—	—	1,287	74,017
—	—	44	9,000	—	—	—	—	44	9,000
—	—	65	29,500	—	—	—	—	65	29,500
—	—	29	108,800	—	59,485	2	300	31	109,100
—	13,534	—	82,850	15	1,480	—	36,412	—	514,913
—	—	—	—	—	—	—	—	23,792	28,695
—	—	—	—	—	—	—	—	247,324	623,475
—	—	—	—	—	—	9	45	335	1,008
—	—	—	—	—	—	—	—	2,292	18,530
2,575	21,456	—	6,970	—	—	—	—	38,590	320,524
—	—	—	—	—	13,683	—	—	—	13,683
—	71,145	—	—	—	—	—	—	—	71,145
—	—	—	2,050	—	—	—	—	—	31,050
—	16,930	—	5,083	—	16,415	—	9,036	—	79,628
—	$503,985	—	$3,148,205	—	$3,009,688	—	$1,813,179	—	$14,982,298

Relative Importance of Gear.

About nine-tenths of the annual catch in quantity is taken with five classes of apparatus, viz.: (1) seines, (2) lines, (3) pound nets, traps, and weirs, (4) gill nets, and (5) dredges and tongs used in the capture of shellfish. Seines are the most productive, yielding about 30% of the total catch. The principal species taken with seines representing 85% of the catch with this form of gear are: alewives or river herring, carp, sea herring, menhaden, salmon, squeteague, and shrimp. Dredges, tongs, etc., rank second in productiveness, with about 19% of the total harvest, the principal products being crabs, clams, oysters, mussels and other shellfish, except lobsters and shrimp. Lines rank third with about 18% of the total catch. These are highly effective in the capture of ground fish, such as cod, haddock, hake, halibut and pollack and such species as red snapper and for crabs.

Pound nets, trap nets, and weirs are used extensively in the capture of alewives, ciscoes, herring, menhaden, salmon, shad and squeteagues, ranking fourth with about 17% of the annual catch. Gill nets, which exceeded other forms of fishery apparatus in the number of units employed, rank fifth in effectiveness with less than 10% of the catch. The principal species taken are: ciscoes, sea herring, mullet, pike perches, salmon, shad, and lake trout.

Apparatus of Capture.

Seines.

For convenience, seines may be characterized as long, more or less rectangular nets, the upper edge (cork line) of which is provided with floats and the lower edge (lead line) with sinkers to keep the netting distended, while the fish are encircled and drawn out on beach or landing platform or bunted up in a portion of the net to facilitate their removal. Generally speaking, seines may be grouped into two classes: (1) haul, drag or beach seines, and (2) purse seines.

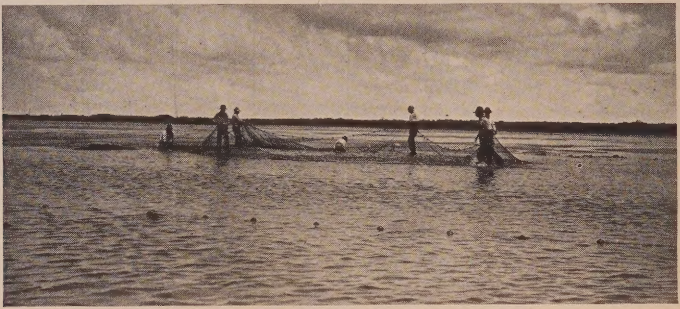

FIG. 91.—Seining for mullet with haul seine in North Carolina.

The former are usually employed in relatively shallow water, along the shores of our rivers, lakes and coastal indentations. The net is laid out in the water parallel to the shore and the two long haul lines used to pull the free ends of the net rapidly to shore or to landing platform, on which the net and its catch of fish are landed. On the other hand, the purse seine is generally used in deep water, either in gulfs and bays, or at sea at varying distances from the shore, in the capture of fish which school at or near the surface, the purse seine being laid out around the school and the bottom pursed or shirred together by the purse line to prevent the fish from settling and thus escaping. While the variations in the type of purse seine are comparatively few in number, the variations in construction of the haul seine are innumerable.

Haul, Drag or Beach Seines.—These vary in length from the small minnow seine of five or ten yards up to seines of 2,500 yards or more. The meshes in the webbing will range from one-fourth inch bar measure up to six inches or more. In some cases the net is rectangular; in others the ends are tapering, the center of the net being much deeper, in some cases lengthened into a bag or bunt, into which the fish collect and cannot readily escape. The center, bunt or bag is usually of smaller meshes than the wings. To the end of each wing is attached a brail, which holds apart the cork and lead lines and to which are attached the hauling lines.

The seines used in our interior waters range in length from about 50 to 250 yards, and in depth from 10 to 20 feet, the size of mesh ranging from one to three inches. In the Columbia River salmon fisheries, the seines range from 200 to 800 yards in length, with a bag about 100 yards long. In this fishery, the net is laid out in a semicircle, one end (shore end), which is about one-third the width of the off-shore end, being landed first. Large seines of this character are usually landed by means of power or drawn ashore by teams of horses. Large seines have long been of special importance in the shad and alewife or river herring fisheries of Maryland. Virginia and North Carolina. At the head of Chesapeake Bay, the salting and canning of the river herring sometimes being conducted on floating factories at some distance from shore, the seine catch is landed on a huge platform over an apron of wood, which extends down to the bottom.

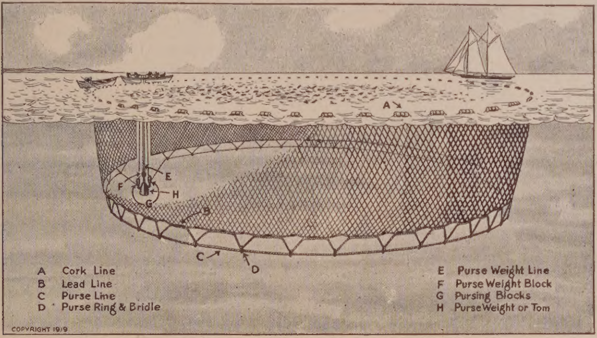

FIG. 92.—Diagram of purse seine about to be pursed.

Purse Seines.—This form of gear is extensively used in the fishery for menhaden. In 1912, there were 274 of these seines valued at $271,000 in use in this fishery. These seines vary from about 270 to 400 yards in length, and 18 to 20 yards in depth, with one and three-fourths inch mesh. In the bunt of the net, which bears the weight of the fish when the seine is pursed, the webbing is of No. 15 and No. 18 cotton twine. In other parts the net is made of No. 20-9 or No. 20-12 twine. The purse line, about 300 yards in length, is of No. 36 thread, Russian hemp. The brass rings through which the purse line passes are four inches in diameter and weigh one and one-half pounds. These are suspended from the lower hanging line on beckets or loops each 6 to 12 inches long placed at intervals of 7 to 10 yards; the final rings being about 20 yards from the end of the net. The corks vary from 3 to 4½ inches in diameter, the larger ones being placed in the central part of the cork line in bunches of three or four quite close together. From 2,000 to 3,000 corks are required. These seines seldom last more than one season and cost considerably in excess of $1,000.

When the school of menhaden is sighted, the two seine-boats, each carrying half of the seine, leave the steamer and at the opportune time encircle the school of fish, throwing out the net as they go. When the two boats meet, the "tom," a large piece of lead weighing about 300 pounds, is attached to the purse lines by snatch blocks and dropped overboard to hold the ends of the net before it is pursed. The ends of the net are rapidly hauled into the boat as it is pursed. When the catch has been pursed up the steamer comes alongside and the catch is bailed into the hold of the vessel. The bailing net is a bag 4 feet deep, of cotton twine, hung to a circular frame of iron about 4 feet in diameter and provided with a wooden handle about 12 feet long. The net is hung from a boom directly over the hold and so arranged as to swing back and forth. The net is raised by a small engine and freed of its cargo of fish by a line attached to the bottom of the net. The handle is controlled by a man standing on deck; thus the fish may be handled at the rate of 500,000 per hour.

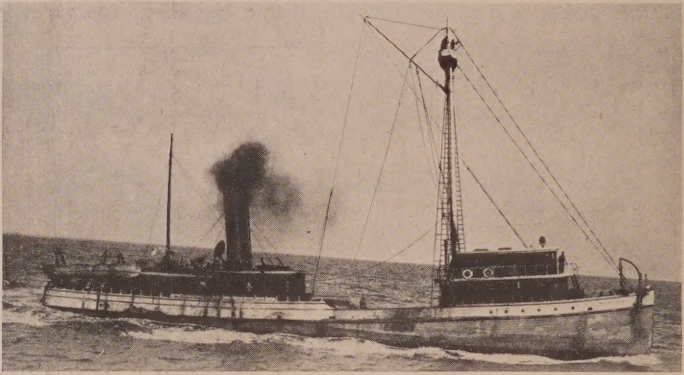

Fig. 93.—Menhaden steamer on Chesapeake Bay. Note the lookout in the crow's nest.

The use of the purse seine in the fisheries for mackerel and menhaden was introduced at a very early date and its employment spread rapidly. In the early eighties, there were about 400 in use in the mackerel fishery and nearly as many in menhaden industry, seines and seine boats being valued at about $440,000. The early mackerel seines were about 200 yards long, 44 yards deep and of 2½ inch mesh. Those in use at the present time are about 900 yards in length and 1,000 to 1,200 meshes deep, of 2¼ inch mesh. Seine boats used with the mackerel schooners are from 35 to 38 feet long, 7½ feet wide and three feet deep. Their life is from four to six years.

In the menhaden industry, the fishery is conducted during the hours of daylight, lookouts in the "crow's nest" at the masthead picking up the schools of fish by the reddish hue of the water. In the mackerel fishery, the lookout for fish is continued into the night. The most favorable time for taking both species is at dawn and again at sundown.

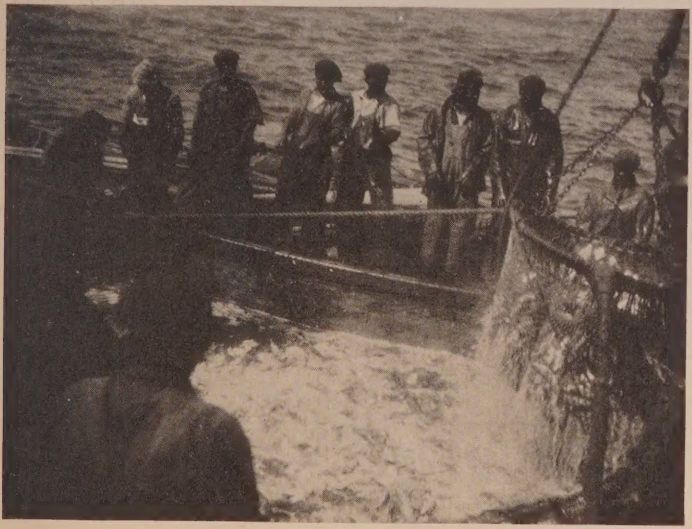

FIG. 94.—Bailing menhaden from purse seine.

Lines.

There are two classes of lines used in the line fisheries: (1) hand lines and (2) trawl lines. In their simplest form these may be compared to the common hook and line and the ordinary set line with which nearly every one is familiar.

Hand Lines.—This form of gear is commercially important in the New England bank fisheries, in the snapper fisheries of the Gulf of Mexico, and in the salmon fishery.

In the New England hand line fishery, a dory hand-line vessel usually carries from 12 to 14 13-foot dories, which are nested on the main deck when not in use. On the fishing grounds, one man goes in a dory and operates two or three lines, depending on depth of water, strength of tide and other conditions. The lines are tarred cotton, weighing from 8 to 10 pounds per dozen, and the leads from 2½ to 3½ pounds each. These are fished in water from 15 to 50 fathoms deep. For bait, salt clams, fresh squid, fresh herring, etc., are used. The dories usually leave the vessel twice each day—before sunrise and again before noon, returning in mid-afternoon for supper and to dress the day's catch, each fisherman being credited with the number taken. With good fishing a doryman will load his boat in a surprisingly short time, as much as three or four loads in a day's fishing. Under favorable conditions, when there is a fleet of vessels on the fishing bank, it is not unusual for 200 or 300 dories to be fishing side by side.

In deck hand-line vessels, i.e., vessels in which the crew fish from the deck of the vessel, the hand lines are the same except that the leads are heavier. Both classes may be seen on the same fishing grounds.

In the red snapper fishery of the Gulf of Mexico, cotton lines about 60 fathoms in length, with two hooks at the end of the line and a sinker of lead, weighing 2 pounds or more, placed 5 or 6 feet from the end, are used from the deck of the fishing schooner. The fishing grounds are found by means of a sounding lead, the sudden deepening of the water showing that a gulch has been reached. Immediately, the vessel is hove to and the lines tried for fish.

In recent years, the use of trolling lines along the coasts of California, Oregon and Washington and more recently in Alaska, for the capture of salmon, chiefly chinook salmon for mild-curing, has increased greatly in commercial importance. Power boats are commonly used in this fishery. Two or more poles of different lengths are set in sockets on each side of the boat, while two lines are set from the stern. The lines are usually forked at the free end thus providing for two hooks, the two branches being kept apart by a wire spreader or by attaching a weight to one of the branches causing it to sink to a lower level. As an indication of the growth of this fishery, the number of boats engaged off the Columbia River increased from about 500 in 1915 to more than 1,000 in 1919. Southeast Alaska furnishes the most remarkable trolling ground. In 1915, ten years after its initiation by white fishermen, 2,170,400 pounds of king salmon and 54,400 pounds of coho salmon were marketed. Alaska fishermen generally use either a Hendryx Seattle trout-bait spoon No. 5 or the Hendryx Puget Sound No. 8, nickel spoons being preferred to brass. In some cases bait, chiefly herring, is used.

In the important albacore and tuna fisheries of California, the catch is made chiefly with hook and line. The fish are trolled for by power boats, and when a strike is made quantities of live anchovies, sardines or other fishes are thrown overboard to attract the school of albacore to the boat. Immediately fishing begins with strong, short poles, short lines and barbless hooks baited with small fish. There is little sport and much hard work, for if biting at all they bite at once and are lifted straight out of the water by sheer strength, shaken from the hook, which is baited at once. It is reported that three men once averaged a ton each in a half hour's fishing. Practically all of the albacore in the California fishery are taken at the surface. Most of the fish are caught by Japanese fishermen, who are especially adept in this work.

Trawl line or Line trawl Fisheries.—Line trawls are used almost wholly in fishing for ground fish—cod, haddock, hake, cusk, halibut, rockfishes, etc. This method of fishing has largely supplanted hand lines in the New England bank and shore fisheries for cod, haddock, etc.

Line trawlers engaged in the market fishery are of two classes—single and double dory fishermen, so called because of the number of fishermen per dory. The dories are 12 and 14 feet long, respectively. Vessels fishing on off shore grounds carry 12 to 16 dories, while those fishing on shore grounds are generally smaller in size and carry fewer dories. Usually each dory is supplied with from 4 to 6 tubs of trawl, each tub representing about 500 hooks. The trawls are coiled in the tubs as they are baited, the baited hooks being placed at the side in rows in such manner that they can be thrown out quickly without fouling. A vessel with 12 dories, each dory operating 4 tubs of trawl, would use 24,000 hooks to a set, and one having 16 dories, 32,000 hooks. On arriving at the bank, only a small portion of the gear is set at first to determine the abundance or scarcity of fish.

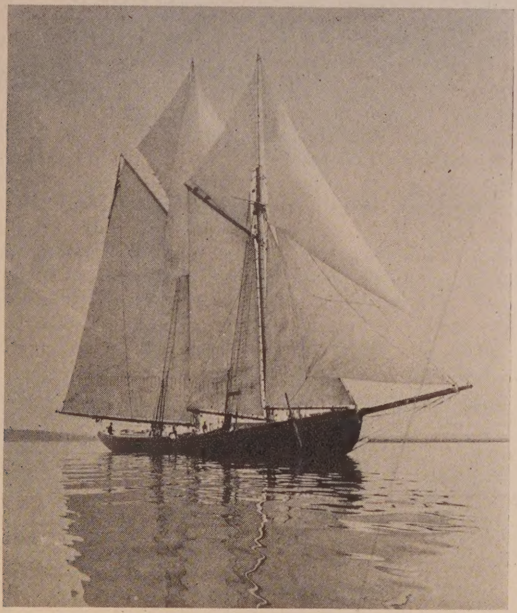

FIG. 95.—Schooner used in the bank trawl line fishery for cod.

Cod and haddock trawl lines consist of two parts, the ground line and the gangings, together with buoys, buoy lines, and anchors. The ground line is a small tarred cotton line weighing about 14 pounds per dozen lines of 25 fathoms each. The gangings to which the hooks are attached are of tarred cotton line weighing about 5 pounds to 600 yards, are two feet long, and are fastened to the ground line at intervals of 5 feet, with some variations.

In setting the trawl, one of the two men in the dory throws the trawl, while the other rows the boat. The buoy line and attached buoy are thrown overboard and the line allowed to run out; the upper end of the trawl line and buoy line are bent on to an anchor, which is lowered over the side of the dory. As the dory is rowed along, the trawl is thrown from the tub until the lower end is reached, when it is bent on to the upper end of the next trawl, and so on until all of the trawls have been set. When the trawls have been set over night, the dories leave the vessel in the early morning to fish the trawls. When two sets have been made during the day, night fishing may be omitted. As the trawls are hauled aboard they are coiled in the tubs so as to facilitate rebaiting and so stored as to facilitate their transfer to the vessel. When fish are plentiful, instead of taking up the trawl, it may be underrun. "Underrunning" consists of removing the fish and rebaiting the hooks, thus permitting of continuous fishing without the necessity of re-setting.

In the Pacific Coast halibut fishery, which supplies the great bulk of this fish used in our markets, each halibut line is about 225 feet long, seven or eight lines, fastened end to end, constituting a "skate" of gear, approximately 1,600 feet long. The gangings are bent on at intervals of about nine feet, each being about five or six feet long with a hook at the free end, the number of gangings per skate of eight lines being 200. For baiting the hooks salmon are preferred, although frozen fresh herring are frequently used. On arrival at the fishing grounds, soundings are made until favorable bottom is located. After a favorable trial set, the dories are put overboard, sets being made at intervals of from one-half to one mile; thus the sets of a vessel with 12 dories will cover considerable ground. It is estimated that such a set will cover 36 square miles of fishing ground. Commonly, two sets are made per day. Fishing operations conducted at distances of 500 to 1,000 miles or more from the home port are continued until the vessel contains all the fish she can carry, or until supplies are needed, when she returns to port and disposes of her catch.

In the California rockfish fishery, similar gear, called set lines, is used, carrying from 3,000 to 4,000 hooks per skate. The ground line is of No. 240 hard-laid cotton thread, and the snoods (gangings) are of No. 24 cotton twine, about 3½ feet long, placed at intervals of from 5 to 5½ feet. Set lines are also widely used in the fresh-water fisheries of our lakes and streams.

Pound Nets, Trap Nets and Weirs.

Inclosures formed by fences of wooden stakes and intertwined with branches, placed at advantageous places in stream, lake or sea, have long been employed in the fisheries. The openings to such traps are so placed that the natural course of the fish leads into the trap, and once in it is difficult to find the exit. In many cases a long fence (leader), extending from the shore to the mouth of the trap, serves as an additional aid in deflecting the fish into the mouth. As there are innumerable variations in the form and construction of these forms in use in American fisheries, only a few of the more typical will be referred to in this chapter. Of these the weirs are the most primitive and will be described first.

Weirs.—Weirs of brush, "brush weirs," are extensively used in the sardine-herring fishery of Maine. The weirs are usually located at a point of land that extends out into the water for some distance, or in channels, frequently between islands or ledges, where the tide is strong, to take advantage of the tendency of the herring to remain in the strong current. The main body of the weir is a large circular or heart-shaped inclosure, formed by driving posts and smaller stakes in between into the channel bottom. The smaller posts are usually fastened together by stringers, fastened to the tops of the larger posts. Fine brush is then interwoven horizontally, between the small posts, completing the inclosure. In some of

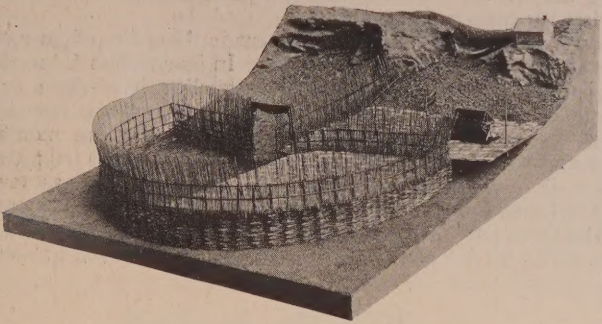

Fig. 96.—Model of a brush weir for sardines and herring (Maine).

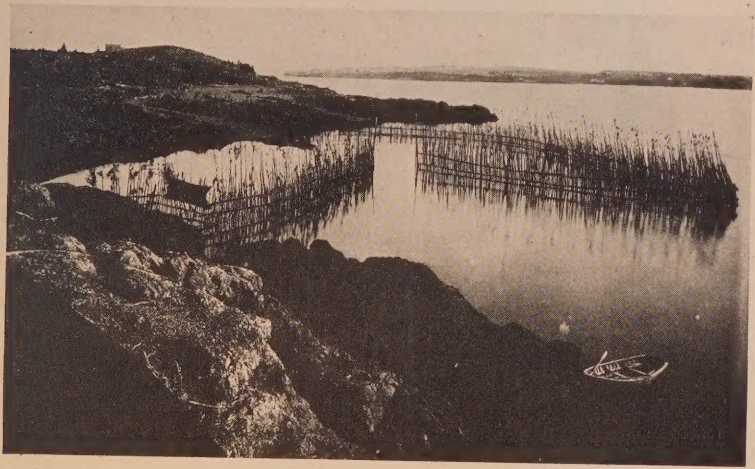

Fig. 97.—Sardine-herring brush weir, Maine.

the newer weirs, netting or webbing replaces the branches. A lead of brush, extending from the shore to the mouth of the trap, deflects the fish into the trap. In fishing the weir, a net is dropped over the mouth of the trap, and the fish captured with a small purse seine, the fish being bailed into dories, for transfer to the boats.

Pound Nets or Traps.—The investment in this form of gear is greater than for any other in use in our fisheries. In its simplest form, the pound net consists of three parts—the leader, extending from shore or shallow water into deeper water, which deflects the fish into the trap inclosure; the heart, a heart-shaped inclosure with its apex at the mouth of the inclosure and its sides extending shoreward and outward from the end of the leader, its ends curved in toward the leader, as well as toward the apex. The heart serves to further deflect the fish toward the mouth of the trap. The third part of the trap is the pot or crib, usually rectangular in shape, in which the fish are captured. The leader is formed by poles driven into the bottom, connected with coarse meshed webbing, extending from the bottom to or slightly above the surface of the water at high tide. The leader may vary in length from about 150 feet up to 1000 feet or more, the size of mesh varying from about 6 to 12 inches. In a typical trap, the leader is 400 feet long; the wings each 68 feet long, with 2 elbows nearly at right angles, and the pot 22 by 28 feet. The size of the openings between the wing ends is 16 feet and the depth of the net is 18 feet, being set in water 20 feet deep. The leader is supported by 18 stakes and each wing by 14 stakes. The size of the mesh in the leader is 12 inches, in the wings 3 inches, and in the pot 2½ inches. The bottom of the pot is covered with netting which can be raised when the trap is fished.

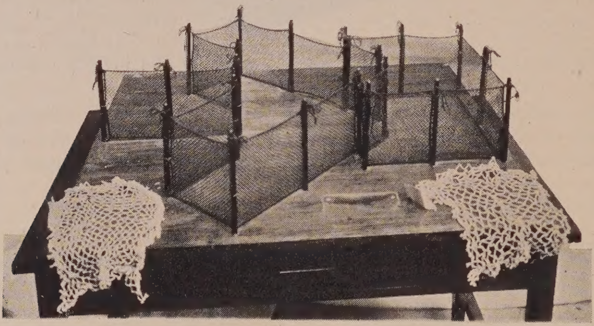

FIG. 98.—Model of a Great Lakes pound net.

There are many variations to the type described. The wings of the heart may be curved or angular; they may project into the crib or pocket or the entrance into the pot may be by means of a funnel made by drawing the front wall of the pot inward, and the wings may or may not have a bottom. Instead of a single heart there may be several. Some pounds are provided with an additional pot, entirely closed for holding the fish for favorable market conditions or for some other purpose. In some traps, wire netting is substituted in all parts except the bottom of the pot which of necessity must be of flexible material. Traps of the type described are rarely set in water more than 100 feet deep.

In deeper water or where the bottom is rocky, so that piles cannot be driven, floating traps are used. These follow the design of the ordinary trap. In the salmon fisheries, such traps are made of logs, 20 to 26 inches at the butt, bolted and braced together in one solid frame. Suspended from this frame, passing through the logs, are 2½ inch pipes, extending down in the water for thirty feet. Midway of their length and at the lower ends are eyebolts, to which the web is drawn down and fastened, thus keeping the webbing in place as well as if the pipes were driven piles. The lead is also a continuation of the frame, of logs bolted together with suspended pipes and netting. Brush weirs are also used in the salmon fishery.

The practice of setting a series of pound nets in a line from shore out into water as deep as it was practicable to construct them, has led to abuses. Thus in rivers, it has happened that such lines from one shore would sometimes overlap those from the opposite shore, practically closing the stream to the passage of fish as well as interfering with navigation. Comparable conditions formerly existing in the important shad and herring fisheries of the Chesapeake Bay district including tributaries, threatened these fisheries and led to corrective legislation, such as limiting the distance from shore in a given stream for which it is permissible to set such gear. The Army Engineer's Office, in keeping waters open to navigation, has materially aided in lessening this menace. In considering legislation restricting the use of pound nets, it should be remembered that this form of gear is one of the most effective in use, and generally no more destructive than other forms of gear. It therefore represents one of the most economical and effective forms of gear in our fisheries. The investment in this form of gear exceeds $6,300,000 and the investment in boats and other equipment used in the pound net and weir fisheries will greatly add to this amount.

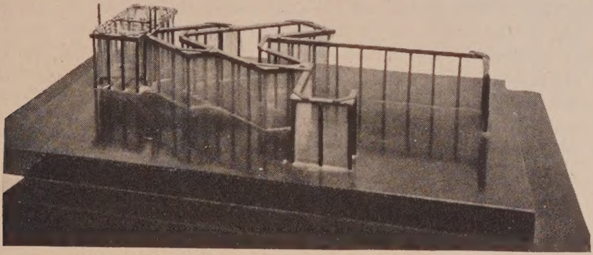

FIG. 99.—Model of a floating salmon trap.

Gill Nets.

As the name indicates, fish are caught in gill nets by becoming entangled in the netting, the size of mesh used in a particular fishery permitting the passage of the head of the fish, but not the body, thus the fish is "gilled" and cannot escape. To be effective such nets must be obscure in the water and of sufficient strength to hold the struggling captive, without tearing the net. Such nets are usually of fine thread, mostly of linen, although cotton is more generally used than formerly. For fishing they may be anchored or staked, i.e., held at a fixed point or drifted, i.e., carried along by current or tide. They may be so hung as to fish at the surface, at intermediate depths, or at the bottom. They are rectangular in outline, with floats and leads along the upper and bottom hanging lines respectively, to keep the net properly distended. In some fisheries it is a common practice to tie the nets in series, such series often being of surprising length. Character of netting and size of mesh vary with the fishery in which used, the meshes being as small as one inch, up to 12 inches in fishing for sturgeon and sharks.

Salmon Gill Nets.—This is one of the oldest and most important forms of gear used in the commercial salmon fisheries. Both drift and set gill nets are employed. Linen twine is generally used, the net being hung slack. Drift nets vary from about 150 to 600 yards in length, 24 to 45 meshes deep, of 5¾ to 9½ inch mesh, depending upon locality and species fished for. Drift netting is carried on chiefly in the estuaries of rivers in and near the channels. The net is laid out across the channel, the final third parallel with the shore forming a letter L. They are usually set about an hour before high water and taken up shortly before the following turn of the tide. Streams where they are used should be free from snags and other obstructions. The net is hauled in over a wooden roller in the stern of the boat, the salmon removed from the net and stunned with a blow on the head.

Set salmon gill nets are similar in form. They vary in length from 20 to 200 yards and 35 to 65 meshes in depth. These are more often operated in the upper reaches of the rivers.

This form of gear is also highly important in the Atlantic Coast shad fisheries. Many are undoubtedly familiar with the drifters in such rivers as the Delaware and Potomac, slowly drifting along in their small boats with the tide, to prevent passing vessels from fouling their nets or underrunning the nets to remove the fish entangled in the fine webbing. It has long been a common practice among such fishermen to buy the twine and make their own nets during the winter season. Gill nets have been used in the fisheries for cod and haddock in the New England fisheries and for cod in our north Pacific waters. About 1915, John N. Cobb carried on experiments with this gear in Pacific waters and was instrumental in their introduction in the cod fisheries. These nets were 125 yards long, made of 12/3 linen cord, 15 meshes deep of 3¾ inch mesh. White cedar floats, 2 inches by 5 inches, 50 to a net with 7 ounce leads on the lead line, placed opposite the floats, are used. As in the Great Lakes fisheries, a net lifter is employed. The use of the lifter, successfully, requires skilful handling of the vessel, to avoid putting too much strain on the net or machine and to keep the vessel nearly over the incoming net. Cod and haddock nets are set at the bottom. In upper Chesapeake Bay the fishermen catch striped bass or rock by drifting their nets as close to the bottom as possible, this method being in vogue in the winter or early spring.

Trammel nets represent a modification of the gill net. Instead of a single netting there are three parallel lines of webbing, the outside webs being coarse-meshed while the inside web is fine-meshed. The fish swims through the outer web, hits the fine web, carrying it through one of the meshes of the coarse webbing on the opposite side, thus forming a pocket from which he cannot readily escape. It has an advantage over the regular gill net in that the fish will remain alive for a much longer time. In the shore fisheries of the Gulf States, the meshes of the outside webs are 5 to 6 inches and the inside web of 1¼ inch web. A trammel net used in southern California was 400 yards long by 5 yards deep. The small web was of 7½ mesh and the outer webs of 18 inch mesh.

Otter Trawl and Other Bag Net Trawls.

Gear of this class, the chief feature of which is a large bag net, is drawn through the water over the bottom, at the surface or at intermediate depths. The principal types are: otter trawls, beam trawls, and paranzella nets.

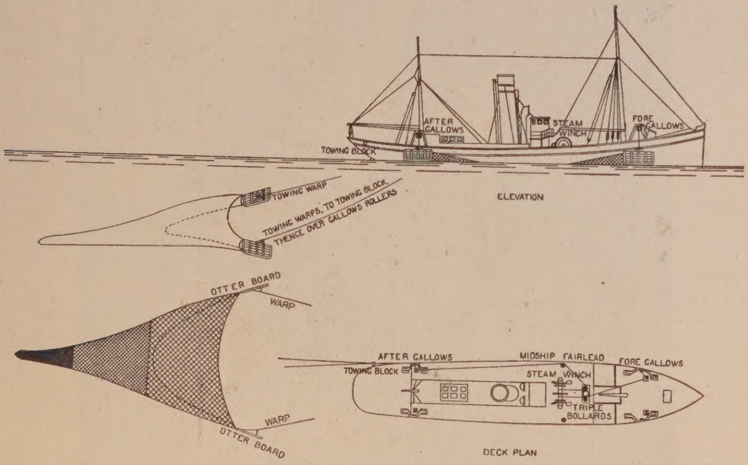

DIAGRAM OF STEAM TRAWLER
SHOWING FISHING GEAR

FIG. 100.—Steam trawlers are largely used in the ground fish fishery on the Grand Banks.

Otter Trawl.—This very effective gear is in use on the banks off our north Atlantic Coast and in the fisheries of the northern European countries in the deep sea fisheries. The typical steam otter trawler in use out of the ports of Boston and Gloucester, Mass., is a two-masted steel steamer, about 115 feet long, 22-foot beam, depth 11 to 12 feet, equipped with 450 H.P. engines, and of a gross tonnage of 248 to 296 tons. Just forward of the wheelhouse, which is situated amidships, is the trawling winch, consisting of two steam driven drums, on which are wound the two wire cables which operate the net.

The otter trawl is a large, flattened, conical bag, the mouth of which is held open by two large boards, "doors," one on each side, to which are attached the towing warps by chain bridles, so adjusted that as the trawl is towed along over the bottom, the resistance of the water causes the boards to pull away from each other, each board and attached warp operating on the same principle as a kite. The nets are about 150 feet long, of strong manila twine, of 3 inch mesh in the forward third, 1½ inch mesh in the central portion, and of doubled twine in the last third or cod end, which reduces the size of the mesh to about 1¼ inches. A foot line of wire cable is wound with rope to give it a diameter of about 4 inches. This helps to keep the line from cutting into the bottom and thus reduces the wear on the net. The foot line is about 140 feet and the head line 110 feet long; the shorter head line holds the top of the mouth considerably in advance of the bottom. Most of the nets in use are imported, although an effort was made during the war to manufacture them in this country. The otter boards are about 10 feet long by 4 feet high and 2½ inches thick and are heavily reinforced with iron.

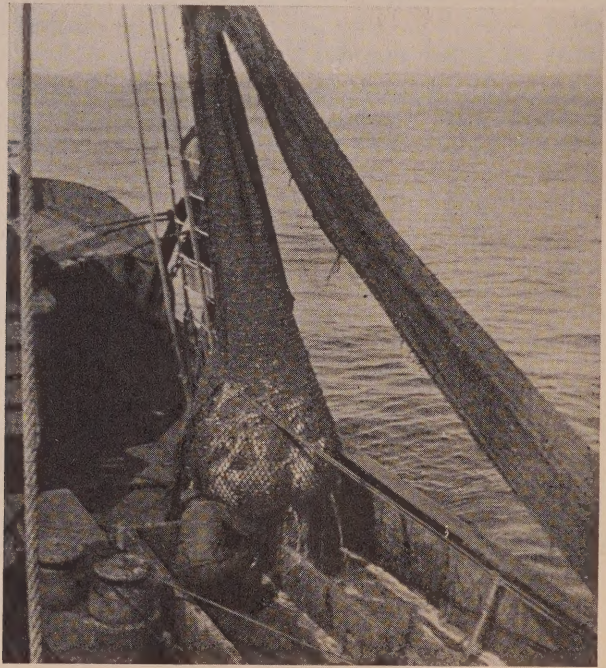

FIG. 101.—Releasing the "catch" of the otter trawl.

The net is towed along the bottom at the rate of from 2 to 3 miles per hour, usually for about 1½ hours. As soon as one haul is landed, the net is put over for another haul. Although the usual trip of the trawler may land from 50,000 to 175,000 pounds of haddock and cod as well as other ground fish, considerably larger fares are sometimes landed at the home port. As this is written, April 20, 1923, a report from Boston announces the arrival of the steamer *Tide* with 250,000 pounds of fish, of which 210,000 pounds were haddock.

On the Massachusetts coast, particularly in the region about Nantucket, large quantities of flounders are taken each year with small otter trawls, operated by small power boats. In 1915, otter trawls were introduced in the shrimp fisheries of the south Atlantic and Gulf states and rapidly supplanted other forms of gear, particularly seines, used in this fishery. Three years later there were nearly 800 otter trawls, valued at about $36,000, in use in the fisheries of these sections, of which 378, valued at $22,000, were credited to Florida.

Beam Trawl.—In this the bag net is attached to a beam, with iron frames, or runners, at its ends. The runners serve to prevent the net from burying in the mud and, in combination with the beam, to hold the mouth of the net distended. This type of gear is useful for scientific collecting, but is little used at present in the commercial fisheries. Formerly, its use was quite extended and led to the development of the otter trawl.

Paranzella Net.—This net has been in use on the Mediterranean for a long period of time and was introduced into the fisheries of California about 1876. It is a heavy and strongly constructed net, for dragging on the bottom, about 96 per cent of the catch consisting of soles and flounders. The nets vary from 50 to 70 yards in length and are made in several sections or "pieces" (4 to 8). The net is rectangular in cross-section, with a door at the posterior end for removing the fish. The net is towed by two 60-foot, or more, sea-going fishing vessels. The towing warps are of 3½ inch hard manila, 1,400 to 1,600 yards long. The towing vessels are separated by a distance of about 250 yards and the towing speed varies from about 2½ to 4 miles per hour.

Other Fishery Apparatus.

Many other forms of fishing gear in addition to those described on preceding pages are in use in American fisheries, brief mention of one or two of which follow.

Fyke Nets.—The fyke net is a long bag net distended by a series of hoops, with or without side wings, which serve to deflect the fish into the funnel mouth. The number of hoops varies from 2 to 15, the usual number being 3 to 6, and the first hoop is usually larger than the others. The hoops are usually from 2 to 6 feet in diameter. This form of gear is largely used in the fresh-water fisheries for such species as buffalo fish, carp, catfish, fresh-water drum, yellow perch, and suckers.

Eel Pots.—Considerable numbers of these are used on the Atlantic seaboard from New York south to the Carolinas in the capture of eels. They range from 1½ to 3 feet in length and 6 to 10 inches in diameter. They are cylindrical, tapering or rectangular, with a frame covered with

TABLE 30

PERCENTAGES OF THE TOTAL CATCH OF EACH SPECIES TAKEN WITH THE MORE IMPORTANT CLASSES OF FISHERY APPARATUS[1]
(Computed from Bureau of Census Report—"Fisheries of the United States, 1908")

Species	Lines	Gill Nets	Seines	Pound Nets, Trap Nets and Weirs	Fyke and Hoop Nets	Trammel Nets	Pots, Traps, etc.	Dredges, Tongs, etc.	All Other Apparatus[2]	Catch in Millions of Pounds
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Total	18.1	9.6	30.2	16.6	2.0	0.8	1.3	19.0	2.4	1,893.4
Alewives	—	2.5	20.5	73.5	—	—	—	—	3.5	90.0
Bluefish	49.5	26.6	16.7	7.0	—	—	—	—	0.2	7.6
Buffalo fish	4.0	—	43.0	5.0	39.0	7.5	—	—	0.6	16.7
Butterfish	—	2.4	3.0	94.0	—	—	—	—	0.6	6.9
Carp	2.5	2.0	56.7	2.8	23.4	12.0	—	—	0.6	42.8
Catfish	39.5	—	21.4	8.5	25.1	3.7	—	—	1.8	17.8
Ciscoes	—	60.0	—	39.7	—	—	—	—	0.3	41.1
Cod	94.5	1.9	1.4	1.6	—	—	—	—	0.6	110.0
Croaker	11.5	5.4	17.5	62.5	—	1.9	—	—	1.2	8.1
Cusk	100.0	—	—	—	—	—	—	—	—	6.3
Drum, fresh water	12.4	—	13.6	35.6	33.5	3.7	—	—	1.3	6.5
Flounders	17.3	3.5	7.0	18.7	12.7	8.6	—	—	32.2	23.3
Haddock	97.0	—	2.4	—	—	—	—	—	0.6	60.0
Hake	99.0	—	—	—	—	—	—	—	1.0	34.3
Halibut	99.9	—	—	—	—	—	—	—	0.1	34.4
Herring, sea	—	8.8	29.8	56.5	—	—	—	—	5.3	130.0
Mackerel	—	23.4	66.7	8.7	—	—	—	—	1.2	12.7
Menhaden	—	0.5	94.5	5.0	—	—	—	—	—	394.8
Mullet	—	67.5	22.0	—	—	8.7	—	—	1.8	33.7
Perch, yellow	—	30.4	6.4	31.8	28.3	—	—	—	3.1	7.9
Pike perch	1.7	53.0	—	41.5	2.8	—	—	—	1.0	15.2
Pollack	68.3	2.0	23.2	6.4	—	—	—	—	0.1	29.5

[1] Exclusive of Alaska. Species for which catch in 1908 exceeded 5,000,000 pounds.

[2] Includes bag nets, bow nets, cast nets, cockle nets and traps, dip nets, paranzella nets, shrimp nets, stop nets, wheels, beam trawls, as well as apparatus listed.

Note:—The species listed represent about 90 per cent of the total catch of fish and fishery products in the U. S.

Salmon	—	49.0	18.6	31.8	—	—	—	—	0.6	90.4
Scup	7.5	—	21.6	70.5	—	—	—	—	0.4	8.4
Sea bass	87.5	—	5.5	6.1	—	—	—	—	0.9	6.4
Shad	—	56.0	9.3	32.6	—	—	—	—	2.1	27.6
Snapper, red	100.0	—	—	—	—	—	—	—	—	13.5
Squeteague	4.0	12.2	33.2	48.3	0.9	1.1	—	—	0.1	49.9
Suckers	—	8.2	6.2	53.4	26.4	3.3	—	—	1.9	8.6
Trout, lake	11.5	78.8	—	8.8	—	—	—	—	0.9	12.0
Whitefish	—	63.7	—	35.4	—	—	—	—	0.9	7.7
Whiting	9.4	2.7	—	87.8	—	—	—	—	0.1	10.3
Shellfish—										
Crabs	45.0	—	—	8.0	—	—	7.1	27.5	12.4	60.6
Lobster	—	—	—	—	—	—	99.1	—	0.9	15.3
Shrimp	—	—	91.0	—	—	—	—	—	9.0	19.0
Clams	—	—	—	—	—	—	—	89.0	11.0	17.0
Oysters	—	—	—	—	—	—	—	98.7	1.3	233.3
Mussels and shells	—	—	—	—	—	—	—	99.8	0.2	90.4

fine meshed wire or netting or splints, with one or two funnel openings, the mouth being about 2 inches in diameter. The pots are baited and are often set singly, but in some localities they are fished in strings of from 10 to 60, from 15 to 60 feet apart. The most common forms of bait are hard crabs, king crabs, shrimp, menhaden, and soft clams.

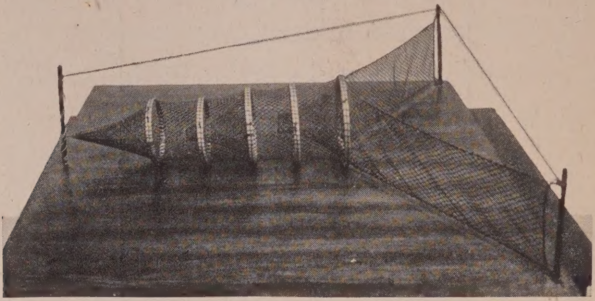

FIG. 102.—Model of fyke net.

Relative Importance of the Various Classes of Gear.

In Table 30 are listed 38 species of fish and shellfish, the catch of each of which in 1908 exceeded 5,000,000 pounds, representing 90 per cent of the total catch of the United States in 1908. In addition the table shows the percentage of the total catch of each species taken with each important class of gear used in its capture. This graphically portrays the almost universal use of lines, gill nets, haul or purse seines, and pound nets, trap nets or weirs, in the fish fisheries and the importance of dredges, tongs and the like in the shellfish fisheries.

In excess of 90 per cent of the catch of cod, cusk, haddock, hake, halibut, and red snapper were taken with lines; more than 50 per cent of the catch of ciscoes or lake herring, mullet, pike perch, shad, lake trout and whitefish with gill nets and more than 50 per cent of the catch of alewives, butterfish, croakers, sea herring, scup, suckers and whiting with pound nets, trap nets or weirs. Fyke, hoop, and trammel nets are confined largely to the capture of fresh-water species such as buffalofish, carp, catfish, fresh-water drum, suckers and yellow perch.

Domestic Production of Fish Nettings.

In view of the heavy annual outlay for fishing gear, this chapter would not be complete without reference to the important part American manufacturers play in providing fish nettings, crab scrape bags, gill nettings and seines of all materials.

In 1914, there were 15 establishments in the United States engaged in the manufacture of such equipment, capitalized at $2,678,000, with 1,058 wage earners, and an output valued at $3,088,000 as compared with 19 establishments in 1919, capitalized at $4,156,000, 859 wage earners, and an output valued at $5,114,000. The fiber materials used in American fisheries are flax, cotton, and manila. On account of its strength and durability, flax is extensively used. As domestic production forms but a very small percentage of domestic consumption and as practically none of the home grown flax is suitable for fish netting, this material is imported and the yarn spun by domestic manufacturers. Most of the imports of flax come from Ireland, where it has been hackled to remove foreign materials and short and uneven fibers. A substantial part of the linen yarn, thread and twine is imported. In 1914, the products of domestic manufacture were 5,707,668 pounds of linen thread, valued at $3,409,136, and 4,953,622 pounds of flax twine, valued at $1,051,684, and imports of thread, twines, and cords of flax, hemp or ramie were 784,936 pounds, valued at $442,674.

The quantities of cotton used in fish netting greatly exceeds those of linen. Manila is the chief material used for making domestic ropes and marine cordage and in the manufacture of otter trawls, most of the latter being imported from England. American manufacturers not only supply the domestic trade but export large quantities, exports to Canada being valued at in excess of $1,250,000 annually.

Our leading foreign competitor in the manufacture of fishing tackle, including hooks, nets, lines, and twines, used in the fisheries, is the United Kingdom, whose exports for the period 1915-1918 averaged yearly $2,829,436, increasing to $5,002,460 in 1919 and declining to $1,064,323 in value in 1920.

Gear of Foreign Fisheries.

The gear used in the Canadian fisheries is for the most part similar to our own. In Great Britain, otter trawls (a development from the beam trawl), drift gill nets, lines and sweep nets (a modified seine) represent the most important types of apparatus. In the Scandinavian countries, trawl and hand lines, gill nets, haul and purse seines and otter trawls are used. Hundreds of purse seines are used in the Swedish herring fisheries in the Cattegat and Skager-Rack, without which the fishery would be of little account. These nets, operated by two powerful motor boats, will average from 20,000 to 35,000 pounds of herring per day and have taken as high as 145,000 pounds. These nets are also used in the sprat and mackerel fisheries. First introduced into Germany during the war, they have since become highly important in the capture of herring and sprat, supplying 3¼ million pounds between December 3, 1922, and January 5, 1923.

In the Mediterranean countries, the fishing gear is more primitive, much less adapted to large scale operations such as we are familiar with. The introduction of power boats has been a highly important factor in the advancement of the fishing industries, particularly in the north temperate zone and failure to adopt its more general use in the tropics has retarded development.

In Japan, a huge bag net, with wings up to 3,000 feet in length and a bag 900 feet long by 250 feet wide at its mouth and 125 feet deep, is used successfully in the capture of amber-fish or yellowtail. Each net is attended by 25 or 30 boats and 150 to 200 men, catches as high as 10,000 yellowtail weighing 200,000 pounds being made. One of the unusual fisheries of Japan involves the use of cormorants—each boat carrying four men and 16 cormorants, catches as high as 700 to 800 fish being made in the course of a night's fishing.

In general, the fisheries of the tropical and south temperate zones are extremely primitive, the crudest form of nets and boats being used, in no way comparable to the high degree of perfection existing in the north temperate zones of North America and Europe.

Net Preservation.

As our fishermen invest annually between $5,000,000 and $7,000,000 in new fishing gear, representing 6 to 8 per cent of what they receive for the fishery products taken, means for lengthening the life of the nets are of great importance. Although the use of preservatives dates back to the "long ago" and some form of preservative is in use in every locality where nets are used, the science of net preservation has been sadly neglected and affords additional evidence as to the general need for technological studies, such as those prosecuted in recent years by the United States Bureau of Fisheries.

The disintegration of nets is caused by several factors, such as mechanical wear and tear resulting from the rubbing of the threads against one another, the floats and leads, the sides of the boat, etc.; by bacterial decomposition and by oxidation resulting from the heating of nets, covered with fish oil, blood and slime stored when wet. In lessening the deterioration caused by these factors, consideration must be given to the particular purpose the net is to serve; thus a preservative suited to pound nets which are left in the water for protracted intervals and exposed to rigorous mechanical wear may be wholly unsuited to gill nets.

In general the processes of preserving nets may be divided into two general classes: (a) those employing tanning materials such as the barks of birch, hemlock, oak, and spruce; and extracts of wood or bark such as catechu, quebracho and quercitron; and (b) the use of such materials as tar (pine and coal), linseed oil, blue vitriol alone or combined with soap, salt, smoke, and creosote.

Extended use is made of the tanning methods, especially in the fisheries of our interior waters. Such treatment is efficacious on netting of cotton or hemp and has the advantage of leaving the nets soft and pliable, without adding materially to the weight.

The use of the tars is more general in our sea fisheries, the nets being passed through hot tar, surplus tar removed and the nets dried. The tars and linseed oil afford physical protection to the netting, filling in the interspaces between the fibers and to a large extent keeping the water away from the individual threads and lessening abrasive action. These add very greatly to the weight of the gear. Tar is used extensively on pound nets, purse seines and other heavy netting.

As a temporary preservative, where it is impracticable to dry the nets, salt is generally used. This is a common practice in the menhaden fishery, where the nets, foul with slime, blood, etc., are piled in the boats for some time without opportunity for drying.

In general, all nets should be washed and dried at every opportunity; they should also be tarred or tanned at sufficiently frequent intervals to obtain the maximum of benefit of the preservative action and protection afforded by these materials.

The investigations of the Bureau of Fisheries to which reference has been made, include the development of a new net preservative—copper oleate—which possesses certain advantages over any preservative heretofore used, as well as a technique for determining the relative value of each of the many factors to be considered in determining the value of a preservative.

As illustrative of the alacrity with which American manufacturers avail themselves of the information gained from such researches, within a few months after the advantages of copper oleate were revealed, some five or six manufacturers were prepared to supply fishermen with this commodity.

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Chapter 14.

Fish as Food.

Characteristics of Fresh Fish: Appearance, Chemical Composition, and Nutritive Value.

Physical Characteristics.

When a fish dies it stiffens almost immediately, the flesh becoming rather firm and elastic. This condition is called rigor mortis and is a guarantee that the fish is perfectly fresh. But since, even under the most favorable storage conditions, rigor mortis gradually disappears in a short time, its absence does not indicate that the fish are not sufficiently fresh to be of excellent quality as food.

The flesh around the large caudal vein and the kidney in fresh fish is light colored. As staleness approaches this flesh becomes discolored by the blood. If this discoloration is found it is evident that the fish has been caught for some time, but does not indicate definitely that the fish is unfit for food. The presence of this reddish discoloration on the ventral aspect of the backbone should cause the fish to be regarded with suspicion and other tests should be made to discover whether the fish is stale or putrid.

Although the personal factor enters so largely into the judging of the condition of a fish by its odor and although fresh fish of different species vary considerably in this respect, yet the use of the sense of smell is invaluable in the examination of fish. Many individuals have difficulty in distinguishing between the odor of fresh fish and that of slightly tainted or stale fish, but few, if any, have trouble in discerning a putrid odor.

It requires considerable energy to strip the flesh from the backbone of a strictly fresh fish, and many pieces of flesh are left adhering to the bone. When the fish becomes stale the flesh comes away readily and comparatively cleanly from the bone. This is another test which may be applied to show the relative freshness of a fish.

The condition of the kidney is a very important criterion in the judgment of the freshness of fish. It is a very diffuse, vascular, and friable organ, and rapidly decomposes, passing through different shades of color, to form a reddish brown jelly-like mass in a few hours at ordinary temperatures. The abdominal walls also break down quickly. In fresh fish they are firm and elastic but as the fish grow stale they lose their strength and become soft and pulpy.

A common criterion applied by nearly every housewife in the purchase of fish is the examination of the gills. The gills of most fish are red in color, with certain specific tints. These tints disappear in about 24 to 36 hours, and the gills become grey and slimy by the third to fourth day if the fish are not kept at a low temperature. This test is not infallible as frequent washing of the fish aids in the retention of the color; moreover, the gills of trawled fish are often paler at the time of capture than those of line fish; and also there are degrees of paleness even among perfectly fresh fish.

The eyes of freshly caught fish are full and prominent with a jet black pupil and transparent cornea, but gradually shrink and become gray in color as staleness develops.

A great deal may be learned concerning the history of the past treatment of fish by a careful examination of their general appearance. The presence of their characteristic sheen and the usual firmness of the scales indicate perfect freshness. If the scales present a patchy appearance on the skin of the fish it indicates either that the fish have been trawled or have been roughly handled.

Anderson[1] summarizes the characteristics of stale fish as follows:

1. Rigor mortis has passed off.
2. Reddish discoloration on the ventral aspect of the backbone.
3. Smell becoming tainted, passing to putrid.
4. Flesh strips off readily and cleanly from backbone.
5. Abdominal walls becoming soft and pulpy, with commencing discoloration and tainted odor.
6. Gills lose characteristic tint, becoming gray and slimy.
7. Eyes gray and sunken.

Chemical Characteristics of Fresh Fish.

The flesh of perfectly fresh fish is acid to litmus but as rigor mortis passes off the reaction changes to neutral, becoming distinctly alkaline as decomposition sets in. The increasing alkalinity of fish during storage is caused by the gradual decomposition of the proteins and other nitrogenous constituents. Enzymes contained in the blood, in the kidneys and other organs of the body are particularly active in effecting this autolytic decomposition. Bacteria contained in decomposing feed in the intestinal tract also bring about the formation of amino acids and amines in short periods if the fish are not eviscerated or refrigerated.

The first chemical reactions of autolysis are chiefly those of the hydrolysis of the proteins into simpler chains of amino acids. Proteins are broken down into proteoses, which are in turn split into polypeptids and amino acids. The end products of the decomposition of these nitrogenous compounds are amines, ammonia, carbon dioxide, methane, hydrogen etc. The exact nature of the end products depends upon the agencies effecting the final decomposition and the amount of oxygen present.

The author[2] found that the rate of formation of amino acid nitrogen in fish was an excellent index of the rate of decomposition of the protein.

[1] *26 Ann. Rept. Fishery Board Scotland* (1907), 37.

[2] *Bureau Fisheries, Doc. 884* (1920); also *Rept.* 1919, appendix 5.

The rate of formation of proteose, polypeptids and amines also gives much information concerning the chemical changes of proteins.

Fats are much more stable compounds and are not affected to any appreciable extent during the ordinary storage of fresh fish, but during refrigeration for long periods as in the preservation of frozen fish, if they are not reglazed often to replace that lost by evaporation, the air comes into contact with the fish, the fat soon becomes rancid and the fish "rusts." Rusting may be approximately estimated chemically by determining the amount of free fatty acid present in the fat. Kreis proposed a phloroglucinol test for detecting rancidity, and Kerr[3] developed this method into a roughly quantitative test. However, neither the Kreis test nor the Kerr modification is an entirely satisfactory method for the determination of rancidity in fish fat.

Proximate Composition.

The percentage of fat in different species of fish varies widely. Salmon, shad, herring, butterfish and mackerel are well-known fatty fish whereas cod, haddock, cusk, pollack and flounder have long been recognized as lean fish. Fishermen have observed that certain fatty fish such as the herring and mackerel are much fatter in the late fall and winter than in spring and summer. Moreover, many fish, such as the salmon and shad, are known to be high in fat during the early development of their sexual organs and very lean immediately after spawning.

Many other factors also influence the amount of fat in the individual fish. The larger, older fish are often fatter than smaller fish especially those of the same school as they are stronger and thus are able to seize more food. Female fish during the early development of the ovaries are usually fatter than male fish of the same schools. Fish caught on excellent feeding grounds are fatter than those caught elsewhere.

Clark and Almy[4] made a study of the common food fishes of the Philadelphia markets with especial reference to a seasonal variation in composition and concluded that of the ten marine fishes examined at different seasons of the year nine species showed a definite tendency toward a seasonal variation in composition. Their results are given in Tables 31 and 32.

A consideration of their results and a comparison of the many published analyses of fish makes it plain that a single analysis, even if based on large numbers of individuals, cannot be accepted as representing a typical composition. The great bulk of the proximate analyses of fish are therefore of little value except that they may be used for the classification of fish into two general groups, viz.: fatty and non-fatty fish (fish of low fat content).

Clark and Almy have shown that the protein content of fish is approximately the same in both fatty and non-fatty fish. They conclude "as the fat content increases the water content decreases, the protein remaining practically the same." This relation is shown by their figures for blackfish, bluefish, Spanish mackerel and shad in Table 33.

[3] *J. Ind. Eng. Chem., 10* (1918), 471.

[4] *J. Biol. Chem., 23* (1918), 483-498.

TABLE 31

PERCENTAGE COMPOSITION OF EDIBLE PART OF FISH

FRESH BASIS

Common Name of Fish	When Caught	Solids	Fat	Ash	Nitrogen				
					Total	Cold Water Soluble	Coagulable	Hot Water Soluble	Ammonia
Bluefish	May 7	23.83	1.54	1.16	3.36	0.760	0.320	0.071	0.0185
Bluefish	Sept. 28	29.04	8.10	1.11	3.26	0.730	0.360	0.085	0.0180
Butterfish	May 19	25.66	5.96	1.49	2.89	0.862	0.498	0.020	0.0162
Butterfish	Oct. 12	30.01	13.52	1.40	2.92	0.850	0.430	0.021	0.0180
Croaker	Apr. 10	20.77	1.25	1.18	2.85	0.813	0.447	0.141	0.0140
Croaker	Sept. 8	24.26	3.23	1.37	—	0.880	0.410	0.130	0.0230
Flounder	Apr. 19	17.54	0.20	1.17	2.56	0.880	0.477	0.117	0.0143
Flounder	Sept. 22	21.59	0.37	1.34	2.54	0.740	0.330	0.200	0.0190
Haddock	Apr. 2	18.32	0.15	1.11	2.33	0.748	0.343	0.147	0.0220
Haddock	Aug. 31	20.83	0.09	1.01	2.59	0.800	0.520	0.150	0.0220
Striped bass	Apr. 16	25.70	3.58	1.26	3.21	1.153	0.719	0.102	0.0170
Striped bass	Oct. 16	19.83	2.98	1.26	3.07	1.050	0.650	—	0.0166
Sea bass	May 12	22.02	1.61	1.23	2.98	0.967	0.532	0.106	0.0159
Sea bass	Sept. 14	19.44	1.60	1.09	—	0.970	0.700	—	0.0220
Spanish mackerel	June 4	33.01	12.59	1.20	3.13	0.846	0.458	0.055	0.0185
Spanish mackerel	Oct. 26	35.70	16.24	1.11	3.09	0.890	0.570	0.102	0.0240
Weakfish	May 1	21.41	2.34	1.25	2.83	1.118	0.851	0.203	0.0134
Weakfish	Sept. 25	19.35	0.52	1.20	—	0.820	0.500	0.290	0.0150
Shad (male)	Apr. 2	35.32	14.43	1.34	3.18	1.112	0.621	0.074	0.0160
Shad (female)	Apr. 13	34.17	13.93	1.40	3.00	1.147	0.685	0.063	0.0182
Shad (female)	May 22	26.00	5.87	1.29	2.91	0.980	0.549	0.058	0.0191
Shad (female) spent	June 19	23.38	2.95	1.53	2.98	0.975	0.549	0.182	0.0178

TABLE 32

PERCENTAGE COMPOSITION OF EDIBLE PART OF FISH

CALCULATED ON DRY BASIS

Common Name of Fish	When Caught	Fat	Ash	Nitrogen				
				Total	Cold Water Soluble	Coagulable	Hot Water Soluble	Ammonia
Bluefish	May 7	6.45	4.87	14.10	3.19	1.35	0.30	0.078
Bluefish	Sept. 28	27.86	3.81	11.21	2.51	1.24	0.29	0.061
Butterfish	May 19	23.27	5.81	11.28	3.36	1.94	0.08	0.063
Butterfish	Oct. 12	45.02	4.66	9.72	2.83	1.43	0.70	0.059
Croaker	Apr. 10	6.02	5.68	13.72	3.91	2.15	0.68	0.067
Croaker	Sept. 8	13.30	5.64	—	3.62	1.69	0.54	0.094
Flounder	Apr. 19	1.14	6.67	14.60	5.06	2.72	0.67	0.082
Flounder	Sept. 22	1.71	6.20	11.76	3.42	1.90	0.90	0.087
Haddock	Apr. 2	0.81	6.06	12.72	4.08	1.87	0.80	0.120
Haddock	Aug. 31	0.42	4.84	12.43	3.84	2.50	0.72	0.105
Striped bass	Apr. 16	13.94	4.90	12.50	4.48	2.80	0.40	0.066
Striped bass	Oct. 16	15.01	6.35	15.47	5.39	3.29	—	0.084
Sea bass	May 12	7.32	5.59	13.55	4.39	2.42	0.48	0.072
Sea bass	Sept. 14	8.22	5.60	—	5.08	3.55	—	0.113
Spanish mackerel	June 4	38.14	3.63	9.48	2.56	1.39	0.17	0.056
Spanish mackerel	Oct. 26	45.47	3.10	7.38	2.49	1.60	0.29	0.067
Weakfish	May 1	10.94	5.85	13.23	5.53	3.98	0.95	0.063
Weakfish	Sept. 25	2.68	6.19	—	4.63	2.58	1.49	0.077
Shad (male)	Apr. 2	40.85	3.80	9.01	3.15	1.768	0.21	0.045
Shad (female)	Apr. 13	40.75	4.10	8.78	3.35	2.005	0.18	0.053
Shad (female)	May 22	22.58	4.97	11.20	3.77	2.113	0.23	0.074
Shad (female) spent	June 19	12.62	6.54	12.75	4.17	2.348	0.78	0.076

TABLE 33

RELATION BETWEEN THE AMOUNTS OF FAT, WATER AND NITROGEN IN THE FLESH OF FISH

Kind of Fish	Water	Solids	Fat	Fat-free Solids
	Per cent	Per cent	Per cent	Per cent
Blackfish	79.10	20.90	0.15	20.75
Bluefish	70.96	29.04	8.10	20.94
Spanish mackerel	66.99	33.01	12.59	20.42
Shad	64.68	35.32	14.43	20.89

Dill has studied the seasonal variation in composition of the California sardine[5] *Sardinia cærulea* and the yellown tuna, bluefin tuna, sablesh, barracuda and the California mackerel[6] *Scomber japonicus.* The results of his work agree with those of Clark and Almy in that he found that there is a great variation in the composition of the same species of fish at different seasons of the year and of individual fish from the same school or different schools. However, he concludes that these variations are frequently erratic and cannot be ascribed to known factors, and that the variation in the composition of the California mackerel during one season was not paralleled by the next season's variation.

Atwater's[7] classical analyses of the more common food fishes are given in Tables 34 and 35. From what has been said above it is evident that Atwater's data indicate merely the general composition of fish and are not to be considered as the definite composition of the various species.

Nature of Constituents.

Unfortunately relatively little work has been done to determine the exact chemical nature of the organic substances forming the tissues of fish. It is mainly the muscular tissue of fish which serves as a foodstuff and therefore in this chapter its composition will be given the chief consideration. The muscular tissue of fish consists chiefly of water, proteins and more or less fat. The chemical nature of fish fats is considered in some detail in the section on fish oils (Chapter 21), and a duplication of the discussion is unnecessary.

Nitrogenous Compounds.

The nitrogenous compounds occurring in fish muscle are for the most part similar in nature to those found in the muscles of the higher vertebrates but differ from them in containing more collagen and less extractives.

Extractives.—Various writers have shown that histidine, hypoxanthine, carnosine, tyrosine, creatine, and creatinine are the principal organic compounds obtained by aqueous extraction of fresh fish muscle. The

[5] *J. Biol. Chem., 48* (1921), 93-103.
[6] *J. Biol. Chem., 48* (1921), 73-82.
[7] *U. S. Fish Comm. Rept.* 1888, 679-868.

TABLE 34

Proximate Composition of Some Common Preserved Fish

Kind of Food Material	Refuse (bone, skin, etc.)	Salt	Water	Protein by Factor (N × 6.25)	Fat	Carbohydrates	Ash or Mineral Matter	Total Nutrients	Fuel Value per Pound
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Calories
Mackerel, Number 1, salted	19.7	8.3	34.8	13.9	21.2	—	2.1	37.2	1,107
Cod, salted and dried	24.9	17.3	40.2	19.0	.4	—	1.2	20.6	363
Cod, boneless codfish, salted and dried	—	21.5	54.4	26.3	.3	—	1.7	28.3	490
Caviar	—	—	38.1	30.0	19.7	7.6	4.6	61.9	1,479
Herring, salted, smoked and dried	44.4	6.5	19.2	20.5	8.8	—	.9	30.2	726
Haddock, salted, smoked and dried	32.2	1.4	49.2	15.8	.1	—	1.0	16.9	290
Halibut, salted, smoked and dried	7.0	12.0	46.0	19.3	14.0	—	1.9	35.2	916
Sardines, canned	5.0	—	53.6	23.7	12.1	—	5.3	41.1	916
Salmon, canned	14.2	—	56.8	19.5	7.5	—	2.0	29.0	658
Mackerel, canned	—	1.9	68.2	19.6	8.7	—	1.3	29.6	708
Mackerel, salt, canned	19.7	8.3	34.8	13.9	21.2	—	2.1	37.2	1,107
Tunny, canned	—	—	72.7	21.7	4.1	—	1.7	27.5	558
Haddock, smoked, cooked, canned	—	5.6	68.7	22.3	2.3	—	1.6	26.2	499

TABLE 35

Proximate Composition of Some Common Marine Fishes

Kind of Food Material	Refuse (bone, skin, etc.)	Water	Protein by Factor (N × 6.25)	Fat	Ash or Mineral Matter	Total Nutrients	Fuel Value per Pound
Fresh Fish:	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Calories
Alewife, whole	49.5	37.6	9.8	2.4	.8	13.0	277
Bass, sea, dressed	46.8	42.2	10.5	.2	.7	11.4	200
Bass, sea, whole	56.1	34.8	8.7	.2	.6	9.5	168
Bass, striped, dressed	51.2	37.4	8.8	2.2	.5	11.5	249
Blackfish, dressed	55.7	35.0	8.4	.5	.5	9.4	172
Bluefish, dressed	48.6	40.3	10.0	.6	.7	11.3	204
Butterfish, dressed	34.6	45.8	11.8	7.2	.7	19.7	503
Butterfish, whole	42.8	40.1	10.3	6.3	.6	17.2	440
Cod, dressed	29.9	58.5	11.1	.2	.8	12.1	209
Cod steaks	9.2	72.4	17.0	.5	1.0	18.5	327
Cusk, dressed	40.3	49.0	10.1	.1	.5	10.7	186
Eel, salt-water, dressed	20.2	57.2	14.8	7.2	.8	22.8	558
Flounder, common, dressed	57.0	35.8	6.4	.3	.6	7.3	127
Flounder, winter, dressed	56.2	37.0	6.3	.2	.5	7.0	122
Hake, dressed	52.2	39.5	7.3	.3	.5	8.1	145
Haddock, dressed	51.0	40.0	8.4	.2	.6	9.2	159
Halibut, dressed	17.7	61.9	15.3	4.4	.9	20.6	454
Herring, whole	42.6	41.7	11.2	3.9	.9	16.0	363
Mackerel, dressed	40.7	43.7	11.6	3.5	.7	15.8	354
Mackerel, Spanish, dressed	24.4	51.4	16.3	7.2	1.2	24.7	585
Mackerel, Spanish, whole	34.6	44.5	14.1	6.2	1.0	21.3	508
Mullet, dressed	49.0	38.2	9.9	2.4	.6	12.9	277
Mullet, whole	57.9	31.5	8.2	2.0	.5	8.9	231
Perch, white, dressed	54.6	34.4	8.8	1.8	.5	11.1	231
Perch, white, whole	62.5	28.4	7.3	1.5	.4	9.2	195
Pollack, dressed	28.5	54.3	15.4	.6	1.1	17.1	304
Pompano, whole	45.5	39.5	10.3	4.3	.5	15.1	358
Porgy, dressed	53.7	34.6	8.6	2.4	.7	11.7	254
Porgy, whole	60.0	29.9	7.4	2.1	.6	10.1	218

Red grouper, dressed	55.9	35.0	8.5	.2	.5	9.2	163
Red snapper, dressed	45.3	43.7	10.6	.3	.7	11.6	204
Salmon, California (sections)	10.3	57.9	16.7	14.8	.9	32.4	903
Salmon, Maine, dressed	23.8	51.2	15.0	9.5	.9	25.4	658
Shad, dressed	43.9	39.6	10.6	5.4	.8	16.8	408
Shad, whole	50.1	35.2	9.4	4.8	.7	14.9	363
Shad, roe	—	71.2	23.5	3.8	1.5	28.8	581
Smelt, whole	41.9	46.1	10.1	1.0	1.0	12.1	222
Sturgeon, dressed	14.4	67.4	15.1	1.6	1.2	17.9	340
Tomcod, dressed	51.4	39.6	8.4	.3	.5	9.2	163
Tomcod, whole	59.9	32.7	6.9	.2	.4	7.5	132
Turbot, dressed	39.5	43.1	8.9	8.7	.8	18.4	513
Turbot, whole	47.7	37.3	7.7	7.5	.7	15.9	445
Weakfish, dressed	41.7	46.1	10.4	1.3	.7	12.4	240
Weakfish, whole	51.9	38.0	8.6	1.1	.6	10.3	200
General average of fresh fish as sold	41.6	44.6	10.9	2.4	.7	14.0	295

presence of imidazo-ethylamine, leucine, and alanine has also been reported. Okuda[8] found the following amounts of creatine and creatinine in the aqueous extract of the fresh muscle of marine fish:

Name	In 100 Parts of Fresh Substance			In 100 Parts of Dry Matter	
	Water	Creatin	Creatinine	Creatin	Creatinine
Bonito (*Gymnosarda affinis*)	72.165	0.649	0.134	2.011	0.481
Tunny (*Thunnus schlegeli*)	72.402	0.497	0.064	1.800	0.232
Japanese porgy (*Pagrus major*)	77.340	0.754	0.070	3.327	0.308
Shark	79.800	0.655	0.134	3.242	0.663

Distribution of Nitrogen.—Several workers have studied the form of the nitrogen of fish flesh and have shown that it is chiefly albuminous nitrogen. The results of Okuda's[8] analyses of the bonito, the Japanese porgy and the tunny are given in Table 36. Drummond's[9] data concerning the form of nitrogen of herring and cod muscle and the results of Osborne and Heyl's[10] study of halibut muscle are given in Table 37 and are compared with similar analyses of ox and chicken muscle.

TABLE 36

FORM OF NITROGEN IN CERTAIN MARINE FISHES

	Bonito (*Gymnosarda affinis*)		Japanese Porgy (*Pagrus major*)		Tunny (*Thunnus schlegeli*)	
	In 100 g. of fresh flesh	In 100 g. of dry flesh	In 100 g. of fresh flesh	In 100 g. of dry flesh	In 100 g. of fresh flesh	In 100 g. of dry flesh
Water	69.371	—	76.787	—	73.516	—
Dry matter	30.629	100.000	23.213	100.000	26.484	100.000
Total N	4.479	14.621	3.121	13.445	3.549	13.397
Alb. N	3.799	12.401	2.685	11.584	—	—
Non-alb. N	0.680	2.220	0.432	1.861	—	—
Warm water soluble N	1.628	5.314	1.025	4.419	1.530	5.776
Of which protein N	0.948	3.094	0.593	2.555	0.812	3.065
Organic base N	0.189	0.617	0.088	1.379	0.285	1.076
Monoamino N	0.022	0.072	0.016	0.069	0.011	0.041
Ammonium N	Trace	Trace	Trace	Trace	Trace	Trace

From these data it is seen that the analysis of halibut muscle is approximately the same as that of chicken muscle except that the humin nitrogen of the former is somewhat higher. Other observers have reported the humin nitrogen content of chicken muscle as high as 2.74 per cent.

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[8] *J. Coll. Agr. Imp. Univ. Tokyo, 5* (1912-1916), 25-31.
[9] *J. Physiol., 52* (1918-19), 95-109.
[10] *Am. J. Physiol., 23* (1908), 81.

TABLE 37

Form of Nitrogen in Halibut, Cod and Herring Muscle

Protein	Amide N Per cent	Humin N Per cent	Monamino N Per cent	Diamino N Per cent
Halibut	6.70	2.37	60.80	30.20
Cod	5.82	2.30	61.20	30.00
Herring	6.05	2.64	61.40	29.70
Ox	5.51	2.66	64.40	27.30
Chicken	6.63	1.76	61.55	30.27

Composition of the Proteins.—Osborne and Heyl[10] studied the products of hydrolysis of halibut (*Hippoglossus hippoglossus*) muscle and more recently Okuda and Oyama[11] have studied the composition of the proteins of the muscle of the Japanese porgy, *Pagrus major*. Okuda[12] has determined the cleavage products of both the ordinary flesh and the dark flesh ("chiai"), which occurs in the lateral muscles, of the bonito. Okuda, Okimoto and Yada[13] have published similar work on the flesh

TABLE 38

Products of the Hydrolysis of Muscle Proteins in Per Cent of Ash- and Moisture-Free Substances

	Porgy (*Pagrus major*)	Halibut (*Hippoglossus hippoglossus*)	Chicken	Bonito (*Katsuwonus pelamis*)		Cod (*Gadus callarias*)
				Ordinary flesh	Chiai flesh	
Glycine	Absent or trace	Absent	0.68	0.0	0.0	0.0 or trace
Alanine	1.04	?	2.28	2.3	1.1	3.53
Valine	0.60	0.79	?	2.8	1.8	3.88
Valine containing leucine	2.17	—	—	—	—	—
Leucine	8.82	10.33	11.19	10.4	9.2	2.46
Proline	1.22	3.17	4.74	3.1	3.0	1.68
Phenylalanine	4.72	3.04	3.53	4.1	1.6	2.31
Aspartic acid	1.66	2.73	3.21	3.3	3.2	0.61
Glutamic acid	1.63	10.13	16.48	8.1	12.1	5.24
Serine	?	?	?	?	?	0.51
Tyrosine	2.64	2.39	2.16	2.1	2.9	2.46
Arginine	5.15	6.34	6.50	7.8	7.08	6.68
Histidine	2.07	2.55	2.47	3.04	3.16	2.29
Lysine	6.28	7.45	7.94	7.41	6.78	8.35
Ammonia determined	1.32	1.33	1.67	0.64	0.78	0.75
Ammonia isolated	1.04	—	—	—	—	—
Tryptophane	+	+	+	+	+	+
Guanine	—	—	—	0.09	0.12	—
Adenine	—	—	—	0.04	0.1	—
Xanthine	—	—	—	?	?	—
Hypoxanthine	—	—	—	0.08	0.03	—

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[11] *J. Coll. Agr. Imp. Univ. Tokyo*, *5* (1912-16), 365-72.
[12] *J. Coll. Agr. Imp. Univ. Tokyo*, *7* (1919), 1-28.
[13] *J. Coll. Agr. Imp. Univ. Tokyo*, *7* (1919), 29-37.

of the cod. Their results are presented in Table 38 together with Osborne and Heyl's analyses of chicken muscle which may be used for comparison.

Analyses of other species of fish are not available and therefore it is impossible to draw any general conclusions relative to the nature of the proteins found in fish muscle. But apparently they do not differ greatly from those found in chicken muscle. Fish muscle and chicken muscle are much alike in respect to their content of tyrosine, aspartic acid, arginine, lysine, histidine and phenylalanine. In discussing the results of Osborne's experiments Plimmer[14] says "it is curious that, as we pass from the lower forms of life to the higher, the amount of glycine, alanine, leucine, and proline increase." Okuda and Oyama's analysis of *Pagrus major* is curiously low in glutamic acid but this may be accounted for by an error in technique.

Inorganic Constituents.—Atwater's figures (Tables 34 and 35) indicate that the water-free substance of the flesh of the common marine fishes contains from about 3 to 11 per cent of ash. The percentages of phosphoric acid (P_2O_5), sulphuric acid (SO_3) and chlorine in the water-free substance of flesh of a few of the more important marine fishes are given below:

Names of Fishes	Phosphoric Acid P_2O_5	Sulphuric Acid SO_3	Chlorine Cl	Total Ash
Tautog (*Tautoga onitis*)	2.24	1.97	1.03	5.54
Flounder (*Paralichthys dentatus*)	2.70	3.10	—	8.63
Halibut (*Hippoglossus hippoglossus*)	2.11	2.11	—	5.53
Herring (*Clupea harengus*)	1.77	1.77	—	4.83
Mackerel (*Scomber scombrus*)	1.60	1.42	0.68	4.11
Atlantic salmon (*Salmo salar*)	2.05	1.52	0.80	4.94
Shad (*Alosa sapidissima*)	1.76	1.78	0.74	4.58

Atwater gives more detailed analyses of the ash of flesh of haddock and pike in which he compares the composition of the ash of marine and fresh water fishes.

Fish	Ash in Dry Flesh	Percentage Composition of Ash						
		Potash K_2O	Soda Na_2O	Calcium Oxide CaO	Magnesium Oxide MgO	Phosphoric Acid P_2O_5	Sulphuric Acid SO_3	Chlorine Cl
	Per cent							
Haddock	11.26	13.84	36.51	3.39	1.90	13.70	0.31	38.11
Pike	6.13	23.92	20.45	7.38	3.81	38.16	2.50	4.74

It is evident that the marine fish, haddock, contains much more sodium chloride than the freshwater fish, pike.

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[14] The Chemical Constitution of the Proteins. Part 1—Analysis. London, 1917.

Composition of Roe.

No complete analyses of the roe of marine fishes are to be found. Atwater's analysis of shad roe is as follows: Water 71.25%; water-free substance 28.75%; fats 3.78%; non-nitrogenous extractive matters 2.56%; protein (N × 6.25) 20.88%.

Gobley has examined the eggs of carp and determined the following substances: Water 64.08%; paravitellin 14.06%; fat 2.57%; cholesterol 0.27%; lecithin 3.04%; extractive matters 0.39%; coloring matters 0.03%; inorganic matter 0.82%.

Greene[15] followed the chemical development of the ovaries of the king salmon during the spawning migration and concluded that the mature ova are characterized by a high content of protein. The protein is at least seventy per cent higher than the yolk of the hen's egg, but on the other hand the lecithins and neutral fats are less than half the amount stored in the yolk of the hen's egg. Greene's analysis of mature salmon ova follows:

	Total	Water-free	Fat-free
Water	57.68	—	65.60
Solids	42.32	—	34.40
Proteins	26.66	63.01	30.33
Phospholipins	1.5	3.5	1.7
Neutral fats	12.1	28.5	—
Ash	0.66	1.56	0.75

Nutritive Value

Digestibility.

Various scientists have shown that the proteins of fish are as easily digested as those of beef and many other meats. The fats of both fresh and preserved fish have been found to be nearly completely digestible by man. Rozov[16] reported that 98 per cent of the fat of smoked smelt and 97 per cent of that of fresh smelt was digested. Milner[17] studying the digestibility of canned salmon, found in four experiments in which an average of 401 grams of salmon was eaten daily for three days with a simple mixed basal ration consisting of bread, milk, and sugar, that 96 per cent of the protein and 97 per cent of the fat of the fish were retained by the body.

Studying the digestibility of fish proteins with trypsin, White and Crozier[18] found that boiled cod and dogfish were digested more readily than boiled beef.

The results of some recent experiments by Holmes[19] relative to the digestion of mackerel, dogfish, butterfish and salmon by man are shown below:

[15] *J. Biol. Chem., 48* (1921), 59-71.

[16] Comparative Assimilation of Fats from Fresh and Smoked Fish (Russian). Diss., Imp. Mil. Med. Acad. (St. Petersburg), 1891.

[17] *Conn. Agr. Ex. Sta., Rept.* 1905, 142.

[18] *J. Am. Chem. Soc., 33* (1911), 2042-48.

[19] *U. S. Dept. Agr. Bull. 649* (1918).

Number of Experiments	Kind of Fish	Average Amount of Fish Eaten per Day	Digestibility of Fish Protein	Digestibility of Fish Fat
		Grams	Per cent	Per cent
3	Mackerel (fresh)	448	93.1	95.2
3	Butterfish (fresh)	471	91.9	86.4
8	Grayfish (fresh)	440	92.8	94.3
4	Salmon (canned)	355	93.2	93.7

Holmes concludes "considering the experiments as a whole, the very complete utilization of the protein and fat supplied by the fishes studied offer additional experimental evidence that fish is a very valuable food and that its extensive use in the dietary is especially desirable."

Space will not permit the citation of the results of the many other investigations concerning the digestibility of fish and fishery products all of which indicate that fish flesh is as easily and as completely digested as meat.

Modern Concepts of Nutrition.

Until about 1906 most scientists were of the opinion that, if a man or lower animal was fed upon a balanced ration consisting of digestible proteins, fats, carbohydrates and salts in sufficient quantity to liberate in the body the requisite amount of energy, all of the necessary substances for growth and maintenance of weight had been supplied. Since then the researches of Osborne, Mendel, McCollum, Funk, Stepp and many others have shown that the proximate chemical analysis of a food and a knowledge concerning its digestibility, do not give much information concerning its physiological effects. Whether or not a given diet is satisfactory can only be determined by observations on the health of men or animals restricted to it during considerable periods of time. Foods may be well digested and absorbed, but the substances which reach the blood and tissues may not be satisfactory for the nutrition of the body. Some chemical substances which are indispensable to the body may be present in too small amounts to admit of the utilization of the other useful ones which are abundant, but cannot be used to synthesize more complex compounds, no unit of which can be dispensed with.

Because of this an accurate insight into the nutritive value of fish cannot be gained by a consideration of its protein and fat content and the digestibility of these nutritive substances. The chemical nature of the proteins and the content of certain essential factors called vitamins must be ascertained.

Vitamin Content.

It has been found that in addition to the substances formerly supposed to be sufficient, four other substances, as yet unidentified, which are called vitamins are requisite for an adequate diet. The first of the four vitamins to be discovered was designated as fat-soluble A. This vitamin has been found to be present in cod-liver oil, various fish and whale oils, butter, etc.

The second has been called water-soluble B and is the antineuritic vitamin. It is found in yeast, vegetables, nuts, many meats (content low in muscle meats), the germs of grains, eggs, fish roe, etc. The antiscorbutic vitamin is also soluble in water but is not as widely distributed as the antineuritic vitamin. Drummond named it "C." This vitamin is found chiefly in certain vegetables, viz., beets, cabbage, carrots, cauliflower, lettuce, onions, potatoes, etc., and fruits. Cooked fish and most cooked meats are deficient in vitamin C.

But meagre information is available as to the vitamin B content of fish and fishery products. Chick and Hume[20] found it in turbot roe. Drummond[9] reports that cod muscle, herring muscle and salmon muscle are deficient in this vitamin, but that it is present in whole herring. From this it seems reasonable to conclude that vitamin B is present in certain tissues of fish. Whether it occurs in tissues other than the reproductive organs is yet to be shown.

Many workers have reported the presence of the fat soluble vitamin A in fish oils and fatty fish. Cod-liver oil is the most potent source of this accessory food factor. Zilva and Miura[21] examined a sample of crude cod-liver oil which was said to be 250 times as potent as butter as a source of vitamin A. This is probably an unusually high figure but it gives an idea of how large a quantity of this vitamin may be found and an explanation of the remarkable curative properties of this oil in cases of rickets.

Drummond[9] has shown that herring, whale, shark-liver, and cod-liver oils contain the fat-soluble vitamin in relatively large amounts, while lesser amounts are found in salmon and menhaden oils. Mori[22] in 1904 observed that chicken liver and eel fat have for years been used as a domestic remedy for a dietary disease resembling that occurring in rats fed upon rations deficient in the fat-soluble accessory, which seems to indicate the presence of vitamin A in eel fat. Hjort[23] found this vitamin in the fat of both cod and herring roe.

During the last three years there has been much investigation of the relation of certain dietary errors to faulty bone growth. These have proven conclusively that the popular idea which for generations has prevailed, that cod-liver oil possesses a therapeutic value in rickets, is well founded. Since cod-liver oil is very rich in the vitamin A it was postulated by Mellanby that the liberal administration of this dietary factor was a preventive against rickets. Most of the English investigators have accepted the views of Mellanby. In America, McCollum, Simmonds, Becker and Shipley[24] have brought forward strong experimental evidence in support of the view that the substance which plays a rôle in bone growth is not vitamin A, but another substance found in certain fish-liver oils (cod-liver oil, shark-liver oil and burbot-liver oil) in considerable abundance. From its properties it seems justifiable to class it with the vitamins. The substance is quite stable and, according to Zucker, can be demonstrated in the non-saponifiable fraction from the hydrolysis of cod-liver oil.

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[20] *J. Royal Army Med. Corps, 29* (1917), 121-59.
[21] *Lancet, 200* (1921), 323.
[22] *Jahrbuch f. Kinderheilkunde, 59* (1904), 175.
[23] *Royal Soc. Proc., 93* B (1922), 440-49.
[24] *J. Biol. Chem., 53,* 293-312.

The importance of the antirachitic vitamin content of fatty fish can hardly be overestimated. In many countries where dairy products are high priced and vegetables are scarce, as in Alaska, Labrador, and Iceland, all of the common foods are deficient in this vitamin with the exception of herring and other fatty fish. Doubtless its presence in fish fat prevents the outbreak of rickets and other diseases directly or indirectly caused by a deficiency of this accessory factor. Herring dealers might bring this to the public attention by advertisements such as: a herring a day keeps the doctor away.

It should be pointed out here that oxidation destroys vitamin A. Smoking herring may destroy a large proportion of its vitamin content. Further researches should be conducted to determine this point.

In this connection it is interesting to consider the original source of the fat-soluble vitamin in fish oils. Several observers have found it to be present in much of the feed of marine fishes. Hjort[23] showed that it was abundant in microscopic marine diatoms, in the small shrimps and prawns, the roe of fishes, and in green algæ which are the food of many fishes. Coward and Drummond[25] reported this accessory factor to be present in green algæ, but absent or nearly so in red algæ, including Irish moss. Jameson, Drummond and Coward[26] grew a pure culture of a diatom (*Nitzschia closterium*) in sterilized water and showed that the product contained large amounts of this vitamin.

This evidence indicates that fish derive their vitamin from the minute organisms of the water, collectively called plankton, which is directly or indirectly the food of all fish.

The Nutritive Value of Fish Proteins.

Drummond[9] carried out extended feeding experiments with young rats comparing their growth when fed upon a diet, the protein of which was coagulable salmon protein, and one in which the protein was coagulable herring protein, and another in which the protein was coagulable beef protein. He found that the coagulable proteins of the fishes possess a nutritive value quite as high as those derived from beef. However, he adds:

> In considering these results in the light of their application to problems of practical nutrition, it must be remembered, however, that fish muscle is relatively poorer in protein than beef and the majority of other mammalian muscles, while the proportion of substances of the gelatin type which possess a low nutritive value is higher in the case of fish. The nutritive value of the total protein present in equal weights of fish and beef is therefore probably somewhat higher in the case of the latter food.

Summary.

In conclusion, the present knowledge concerning the nutritive value of fish may be summarized as follows: Most species of marine fishes vary in fat content with the season, the abundance of food and the state of development of the sex organs. Certain species of fish such as the mackerel and the herring are very fat at certain times and lean in others, while other species such as the cod and haddock are always of low fat content. The amino acids making up the proteins of fish muscle are the same as those of chicken muscle and they are present in approximately the same proportions.

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[25] *Biochem. J., 15* (1921), 530-9.

[26] *Biochem. J., 16* (1922), 482-85.

Fish contains relatively large amounts of phosphorus which may be of value in nutrition.

The proteins and fat in fish are easily digested and compare favorably in this regard with those of beef muscle. Moreover, the coagulable proteins of fish flesh have been shown to possess as valuable nutritive properties as those of beef muscle.

Fatty fish and especially fish livers contain large amounts of the fat-soluble vitamins and are valuable sources of these essential food factors.

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Chapter 15.

Refrigeration and Cold Storage of Fish.*

By H. F. TAYLOR.†

Importance of Refrigeration.

The three factors of primary importance in the distribution of food are constancy of supply, constancy of demand, and non-perishability of product. If any one of these factors is favorable for any particular article of food, business based upon it can prosper. In the fish business, without some form of preservation, all three factors are unfavorable, and the business contends against great difficulties. Refrigeration serves to take fresh fish from the class of extreme perishables, and thus enables it to be accumulated from a highly fluctuating supply and moved into market as necessary to meet a highly fluctuating demand. There are few industries which depend more fully on refrigeration than the fish industry—we are therefore to deal, in this chapter, with the most important technical method of handling fish, which is the most important and most valuable marine product.

Magnitude of the Fish Freezing and Storage Business.

The business of freezing and storage of fish is practiced much more extensively in the United States than in any other country in the world. There are 274 freezers and cold storage warehouses in the United States which are partly or wholly devoted to handling fish. In 1922 there were frozen 76,256,933 pounds of fish, of which the maximum monthly quantity was 16,330,080 pounds frozen in October, and the minimum was 1,363,942 in March. The principal species frozen were, in descending order of quantities, salmon, all species, including steelhead trout, 12,154,625 pounds; ciscoes, 9,830,722; herring 7,914,029 (mostly for bait); mackerel (except Spanish), 6,092,625; whiting, 6,022,287; halibut, 5,340,304; scup or porgies, 3,105,344; lake trout, 2,162,401; whitefish, 1,431,783; cod, haddock, hake and pollack, 1,162,012.

The fish are frozen during summer and fall and are held till winter and spring. The maximum holding for any one mid-month report was 54,564,022 on November 15, and the minimum was 16,675,445 on March 15. March is usually the period of lowest holdings, the previous year's stock having been moved out and the new year begun. There is some freezing during every month of the year.

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The holdings by sections of the country show the greatest holdings to be in the New England and middle Atlantic States, those around the Great Lakes, and the northern Pacific Coast states. Considerable freezing is done in Alaska, and there are very large freezers in Canada, on both Atlantic and Pacific coasts. There is a large freezer on St. Pierre Island, which is French territory. The size of the freezers ranges upward to 200,000 pounds or more daily freezing capacity, and to about 14,000,000 pounds total storage capacity.

The Nature of the Preservation of Fish by Freezing.

Fish are generally recognized as being highly perishable. Shortly after fish are caught, certain changes begin to take place, at first not undesirable, but which, if permitted to continue, rapidly destroy the suitability of the fish for human food. One of the earliest changes is the coagulation of the cell proteins which causes a general body rigidity or stiffness, known as *rigor mortis.* This condition comes about sooner, and lasts a shorter time, at higher temperatures than at lower temperatures.[1] Rigor mortis is a mark of perfectly fresh fish. Whether fish should be frozen before, during, or after rigor mortis for best results, is an unsettled point; the results of the Dutch investigations [2] seem to indicate that if fish are frozen before rigor the flavor is not so good, but that they are at their best if frozen in rigor. Much of the fish commercially frozen reach the freezer after rigor has passed.

After rigor passes away, other changes of a varied character occur, some of an external character which serve as an index to the quality of the fish, and others of a chemical nature which affect the quality of the flesh. These changes are principally as follows:

(1) *Autolysis.*—The tissues of fish, like those of other animals, contain enzymes which digest the tissues, causing a softening or partial liquefaction, and changes of flavor and odor. These changes in red meats are collectively called ripening, and are desirable because they make the meat tender, juicy and of good flavor. In fish, however, the results are highly disagreeable to the human palate, and ripening or autolysis must be prevented or retarded. A fish whose tissues have been partially autolyzed is soft and flabby. Packing fish in ice retards, but does not arrest autolysis. As long as a fish is kept frozen hard, autolysis is all but arrested, but when the fish is defrosted autolysis again sets in. In the case of meat frozen slowly in air, autolysis is more rapid than in unfrozen meat, if rapidly in brine, more slowly than in unfrozen meat; [3] whether fish behave in this way or not has not been determined.

(2) *Bacterial Invasion and Putrefaction.*—The principal fields of infection are gills, slime of skin, and intestinal tract. The invasion by bacteria begins at once, if the fish are kept at warm temperature, and even at ice temperature proceeds somewhat more slowly. The epithelium of

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[1] See Anderson, A. G., *Fishery Board for Scotland, 26th Ann. Rep.* (1907), Part III, 13-39.

[2] Report of the Scientific Subcommittee of the Commission appointed by the "Nederlandsche Vereeniging voor de Koeltechnik" for Better Methods of Fish Preservation by Improved Methods of Refrigeration. Delft. 1915.

[3] See Fearon, W. R., and Foster, D. L., *Biochem. J., 16* (1922), 504-571.

the intestines is decomposed, then the intestinal walls; the skin and gills are invaded and the smell becomes sour or putrid.

It is mainly to arrest or retard autolysis and bacterial invasion and putrefaction that low temperatures are employed. Fish packed in ice are still edible after many hours or even several days; but they are in prime condition for only a few hours, and they are, after from one to three weeks, unfit for food—though perhaps not dangerous. Fitness or unfitness for food is, of course, a matter of opinion. If more than the briefest storage is necessary the fish must be frozen hard and kept in that condition for the entire period of storage. Freezing and storage if done by the best known methods make possible the holding of fish in good edible condition for upwards of a year.

In the freezing, storing, and defrosting of fish, which are intended to prevent autolysis and putrefaction, certain other undesirable changes may supervene which must be clearly recognized and avoided as far as possible. These are, chiefly:

(1) *Internal Crystallization of Water.*—Fish contains from 65 to 80% water, varying with the amount of fat present. If a small piece of fish is frozen with extreme rapidity, as by immersing in cold mercury or liquid carbon dioxide and examined microscopically, no physical change is observed. But if frozen slowly, as in an ordinary fish freezer, it will be found that much of the contained water has escaped from the cells and muscle fibers and frozen as ice crystals. This phenomenon is accompanied by a rupturing of cell structures, and rapid autolysis and loss of juices on defrosting; the practical result is that fish frozen slowly are not capable of being held long on being defrosted, but must be consumed without delay.

(2) *Desiccation.*—During the periods of freezing and cold storage, the rooms or chambers in which the fish are kept are refrigerated by means of a refrigerant, ammonia or brine, circulating in pipes. These pipes are usually the coldest objects in the rooms, and consequently their surfaces have the lowest water-vapor-pressure. The fish in the freezer or storage are usually warmer than the pipes, and are therefore of higher vapor-pressure. The fish thus lose water by sublimation and the pipes accumulate water as snowy crystals. The fish, unless carefully protected, may in this way rapidly lose weight up to 50 or 60 per cent in a few months. As the fish dries, the skin shrinks and loses its luster, the tissues become like cork, and the fish is not acceptable as food.

(3) *Loss of Flavor.*—Fish that are frozen quickly, heavily glazed, and stored under the best conditions, keep for months with first-rate edible qualities. Yet when storage is unduly prolonged, the fish become insipid, though still wholesome. The chemical reason for the loss of flavor is not known,[4] though it is generally supposed to be caused by evaporation of volatile constituents. In addition to loss of flavor, there is a development, in fat fish, of a rancid flavor due to changes in the fats.

(4) *Rusting.*—On storage, unless precautions are taken, the fishes of fatter kinds become "rusty." By this term is meant an exuding of fat to

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[4] Clifford, W. M., *Biochem. J.*, *16* (1922), 341-343.

Clifford found that the carnosine content of meat in cold storage diminishes. Carnosine has been supposed to be a savory constituent of meat, but when isolated in pure form was found to be tasteless.

the surface, followed by oxidation and possibly polymerization and other changes. When this condition comes about, the fish has a yellowish or rusty appearance, especially around the vent and belly, and on cut surfaces; it is rancid in flavor and objectionable as an article of food, not only because of flavor, but probably also in digestibility. Fat fish like salmon, mackerel and lake trout, rust within two or three months, unless proper preventive measures are taken. The exact nature of the changes which constitute rusting is not understood. Some writers think that shrinkage in the fish during freezing forces the fat out in droplets, and the freezing temperatures should be lower than the freezing point of the oil.

(5) *Incidental Changes.*—Other undesirable things may happen to frozen fish more or less incidentally. Snouts, fins and tails may become broken or scarred, eyes may become glassy, the red corpuscles may be hemolyzed with a diffusion of hemoglobin into the surrounding tissue, the gall bladder may be broken; if frozen in cakes or blocks, the fish are pressed out of shape and individual fish can be separated from the cake only with damage to skin. If frozen in brine, some salt may penetrate the tissues, and the blood may be discolored by the action of salt.

In the descriptive matter to follow, frequent occasion will be had to refer to the several changes here briefly described, and means for preventing the undesirable changes will be considered.

Layout, Construction, and Mechanical Equipment of Fish Freezing Plants.

Fish freezing plants, like almost any other class of plants for commercial operations, vary from simple, crude and inexpensive outfits, to large, complex and costly buildings and machinery. Most of them are on or near the water; many of them are not exclusively fish freezers, but take other perishables for cold storage. Most of them make ice; some do a public fish warehousing business; others are entirely private. The public houses freeze and store fish for customers at a fixed charge; the private houses own the holdings outright, buying fish in the producing season and selling in the consuming season. Practices in freezing and storing fish are not at all standardized; more or less natural, but nevertheless great, differences appear in different regions, and with different species of fish.

Construction and Location of Freezers.

Many freezers are built on piers, so as to be readily accessible by boats, both in unloading fish and in supplying boats with crushed ice through chutes. The better types of freezers are constructed of steel and concrete, with an envelope of corkboard or lith for insulation. Many are of frame construction, with sawdust, felt or other cheaper material for insulating purposes. Usually the machinery, because of its weight and vibration, is located on the ground floor or in the basement. The receiving, washing and panning rooms are usually on the ground floor, but are sometimes on the top floor. The sharp freezers are usually on the first or second floor if the fish are received on the first floor, but in one large freezer in New York, the fish are received on the ground floor, washed, panned and sent to the top floor by continuous chain elevator. In another plant, in Portland, Me., the fish are received on the top floor and conveyed through hatches to the sharp freezers on the floor immediately below. More commonly, however, the sharp freezers are on the first or second floor. They are usually small rooms, with a capacity of from 15,000 to 40,000 pounds, though in some plants larger sharp freezers give good satisfaction. The smaller rooms are usually much longer than wide, and are equipped with shelving made of steel pipe, through which the brine or ammonia circulates. On these pipes the fish are placed to freeze. The large rooms, especially where brine is circulated, permit loading without excessive elevation of temperature, and consequently with quicker freezing; while the small rooms permit loading without interference with the progress of freezing of lots in other rooms. The glazing room is usually located at some point conveniently on the route from sharp freezer to storage. Sometimes there is no definite room for this purpose, a corridor being used; sometimes movable glazing tanks are employed in the storage rooms. More often a glazing tank is permanently built in at a convenient place.

The storage rooms are usually large—much larger than the sharp freezers. The refrigerating pipe coils are arranged on the side walls and on the ceilings. Slatwork is sometimes laid four to six inches from the floors and side walls to permit circulation of air.

Thermometers should be placed in all cold rooms at places convenient for reading, but where they are sure to indicate the true temperature of the rooms. Rooms are electrically lighted, preferably with pilot lights outside all rooms to indicate when lights are on inside. Concrete walls are usually not covered; wooden walls are whitewashed or painted.

Mechanical Refrigeration.

In nearly all commercial plants for freezing fish, ammonia plants are used, and the great majority of these are of the compression type. Absorption machines are used to some extent and give excellent results in that they easily maintain very low temperatures, though they are usually not so economical of operation as the compression machines. Where absorption plants are used, brine is circulated; where compression machines are used, either brine may be circulated or the liquefied ammonia is delivered directly to the coils in the rooms for evaporation. This system is known as the "direct expansion" system. In some cases where steam is used to drive compression machines, there is an amount of exhaust steam coming off at low pressure which is used to operate an absorption machine, brine being circulated through the rooms. Some very large fish freezers are refrigerated by this combination.

Electricity is being used more and more as a prime mover in fish freezing plants; it is simpler, requiring little attention, and where non-peak-load contracts are made with the power companies, compares favorably in expense with steam driven plants.

Where direct expansion is used for chilling the rooms the liquid ammonia is sometimes fed in through expansion valves at the tops of coils, the temperature being regulated by the expansion valve. The so-called "flooded system" makes use of much larger quantities of ammonia to fill to a high level the banks of coils through "expansion" valves at the bottom. In this way advantage is taken of the much better heat conductivity of liquid than gaseous ammonia in contact with the pipes. Many plants operating without flooding the coils often lose entirely the benefit of much of the pipe surface installed.

While it is impossible in the scope of this chapter to discuss the design, construction, installation and operation of the machinery, it is nevertheless of the very greatest importance. Effort is frequently made to operate an expensive plant with low-paid mechanics, who do not understand the machinery either in theory or practice. Naturally the results are highly unsatisfactory. In the smaller plants resort is often had to automatic machines, i.e., plants controlled by thermostats in the cold rooms which stop and start the machinery as necessary to maintain the desired temperature.

Few machines other than ammonia compression or absorption machines are used for fish freezing. In the Fishery Products Laboratory of the U. S. Bureau of Fisheries a carbon dioxide machine is used to obtain very low temperatures for experimental purposes.

For the technology of refrigeration machinery reference should be had to the numerous reference books on the subject.

The Process of Freezing and Storing of Fish.

I. In Air.

The discussion of the methods of handling the fish in refrigerating may be conveniently divided into (1) preliminary handling aboard boats; (2) landing, grading, washing, panning, etc., at the freezer; (3) freezing; (4) glazing; (5) storing; (6) packing, shipping, defrosting and cooking. These divisions will be considered in the order named.

1. Preliminary Handling Aboard Boats.

On small boats near inshore, the catch of fish usually receives no preliminary chilling, but is covered by tarpaulins or other covering and brought ashore. Many species of fish are gutted on the boats because of the danger of putrefaction in the intestines. These include salmon (ocean caught), lake trout, halibut, cod, haddock. Species in which intestinal putrefaction is not so likely to occur are usually brought ashore "in the round"—i.e., not gutted or beheaded. For purposes of freezing it is better, other things being the same, not to gut or behead the fish. When the boats remain out for some days, crushed ice is carried, and as the fish are caught they are gutted and packed in the ice. In the halibut and salmon fishery of the northwest coast, the heads are left on to prevent the leaching out of the cut surfaces that would otherwise occur on exposure to melting ice. The heads are removed on arrival of the fish at the freezer. In the preliminary icing of fish it is important that the ice be crushed fine, so as not to bruise the fish; the fish should go into the ice immediately; the poke or belly cavity should be filled with the ice, and the fish should not be packed too deep, else those in the bottom of the pile are partly crushed. Bruising or crushing greatly accelerates autolysis. Glacier ice is sometimes used in emergency in Alaska, but is very unsatisfactory, and should be avoided. Sometimes a boat may remain out two, or even three, weeks. In such cases the fish caught earlier on the trip are in exceedingly poor condition, being soft, blanched and sour. Such fish should not be frozen.

In the public warehouse freezers, the handling of fish previous to arrival at the freezer is beyond the control of the freezer. They are usually in boxes or barrels in which the fish have been delivered or shipped, and are of unknown history.

2. Landing, Inspecting, Grading, Washing, Panning, etc.

On arrival at the freezer, in the case of fishing boats, the fish are landed usually by an electric hoist. Halibut are generally hoisted in a large net bag, made of ½-inch manila rope. Though highly efficient, this bag bends the fish, the ropes bruise them, and in general serve the fish very roughly. Better means are used for salmon, for example, where strong boxes are lined with galvanized iron, and provided with rope handles at the ends, like a trunk. The two ends are inclined outwardly so that when the contents are dumped, they slide easily and gently on the floor from the inclined ends, bruises being thereby avoided. Pewing or forking, though sometimes resorted to, is extremely objectionable, and should not be practiced. Even when a single tine pew is used, and is stuck in the head, frequent accidental wounds are made in the edible parts of the fish.

When the fish are landed, they are, in the case of halibut, first beheaded. The beheaders work with a meat hook with which they lift the fish by the head, and strike off the head usually by one blow with a heavy butcher knife.

Inspection.—If frozen fish do not occupy the place in public esteem that they should, it is mainly because of insufficient inspection and rejection of poor quality fish. The inspection should be directed to two objects, namely, grading into sizes for purpose of paying the fishermen (where necessary), and grading into quality for acceptability. The size gradings are too numerous and varied to be considered here. The quality grading, however, is of utmost importance in every lot of fish to be frozen, and requires the skilled eye of an experienced judge of fish. Because of a diversity of individual markings of different species, it is impossible to give a key to quality applicable to all species. The characteristics of good and bad fish are tabulated on the following page.

These signs are, of course, not absolute, and furthermore, any particular fish may at any time be somewhere between the "good" extreme and the "bad" extreme.

In the case of halibut, the following grades may be recognized:

1. Fancy fish. White side not stained or colored, no cuts or wounds; black side bright, slime present and clear; blood bright, fresh red; flesh firm and plump, smell sweet.

Good Fish	Bad Fish
Skin and colors bright.	Skin dull, spotted or slimy, colors pale or bleached.
Scales adhere strongly.	Scales loose.
Eyes clear and not sunk in or wrinkled.	Eye cloudy, wrinkled, sunk in.
Gills red.	Gills yellowish, gray, brown.
Flesh firm and elastic. Finger impressions do not remain.	Flesh flabby and soft; finger impressions remain.
Smell fresh, exterior and gills.	Smell stale or sour, especially at gills.
Little slime on skin (usually slime present but clear on halibut).	Skin slimy (usually). In some species the slime is coagulated or lumpy; in halibut the slime leaves the fish.
Body rigid or stiff.	Body flabby or limp.
Fish sinks in water (usually).	Fish floats in water (if very bad). Some good fish, if gassy, will float.

2. Good quality. Fish of high grade, but for any minor cause, not in fancy fish class. As slime leaves body a yellow color begins to appear and spread over white side; blood blanches; flesh becomes softer; these defects in moderate degree, or slight wounds or gray spots on white side, put fish in this class.
3. Off quality. As conditions described under 2 advance, body becomes slimeless and yellow, inside of belly cavity becomes pink or stained; sour odor in belly cavity; flesh soft, impressions of fingers remain, skin wrinkled when tail is bent; fish thin and lean ("logey"). Still suitable for food, but of inferior quality.
4. Fish unfit for food. All the foregoing marks in advanced degree.

A distinction is often made, in public freezers, on the basis of labor required to handle the goods, and charges may vary accordingly. Thus the goods may be classified as large fish, which do not need to be panned, medium or small fish, to be panned, and goods requiring considerable labor in panning like frogs' legs or shad roe.

Washing.—If fish are in the round, they are washed. If butchered, especially the high class fish such as chinook salmon, they are beheaded and the bits of kidney and blood removed by hand with the help of cheap cotton gloves or sometimes brushes. If the salmon are fat, running water is imperative to prevent the smearing of the fish with the accumulated bits of fat. In any fish the use of running water has been shown to be very important. Halibut are washed (1) by laying them on the floor, white sides up, and all arranged with head ends in one direction and playing a hose on them, or (2) by taking each fish, opening the belly cavity and turning a hose into it. (3) They may be washed in tanks, as the other fish are washed. Smaller fish to be panned are washed in a long tank by rousing them. Fresh water is usually used, sometimes sea water. Care should be exercised to get pure, wholesome, drinking water, or pure sea water. Harbor water is unsafe as the fish are to be eaten as food.

Swordfish and sturgeon are butchered and cut into pieces of convenient size, usually about two feet long. Halibut and salmon go to the sharp freezer from the washing. Nearly all smaller fish are panned.

Panning.—The panning tables are located adjacent to the washing tank. Often the tables are small shelves attached to the washing tank or to a draining trough.

The pans are of 20 to 22 gauge galvanized iron; the commonest size is 16 inches x 26 inches x 3 inches deep, holding from 25 to 40 pounds each; average, 30. In any event, they should produce cakes of a size just to fit the final packing box. In some cases the pans have a few holes in the bottom to permit drainage of water, slime and blood. Usually the pans have sloping sides to facilitate removal of the frozen cake. Where the pans have lids, the sides of the pans and lids are straight. Lids help to prevent the evaporation of moisture in the sharp freezer. The fish are placed in regular arrangement in the pans, the arrangement depending on the size and shape of the fish. It is a good plan to pack fish bellies out at least on one side, so that the trade can see the belly side, which most readily indicates the condition of the fish. If the bellies are gassy, it is best to pack bellies inward, so that the glaze does not come off readily. In order to make firm cakes, it is desirable to pack the fish in the cans so that they press firmly together. Too close packing is, however, undesirable because the trade often desires to separate cakes, it being impossible to do this with two-layer closely packed cakes.

The character of the skin has much to do with the solidity of the cake. Fishes which have soft slimy skin, like catfish, eels, lake trout, etc., make substantial cakes, while fishes with rough stiff skin, like the blue and yellow pikes, make cakes that break up rather more readily. Skilled panners, according to data obtained by the writer, require from 1¾ to 2⅙ minutes to pan Spanish mackerel in the pans of size described.

Pans used for freezing fish should be cleaned occasionally by scrubbing with hot water and a good scouring powder.

When the pans are packed, they are placed on trucks and carted to the sharp freezers.

For the best results, it seems permissible to recommend the following practices in the matters dealt with in this section:

1. Land the fish with the minimum of bruising.
2. Do not pew them.
3. Grade for quality very strictly and reject all but unquestionably good fish.
4. Where fish are butchered, remove all blood, particularly the kidney, a bloody strip just under the backbone. Wash in clean, running water—only water that is suitable for drinking.
5. Pan the fish in clean pans, with lids. Put large fish on galvanized iron sheet, not on floor of sharp freezer.

3. Freezing in the Sharp Freezer.

As previously stated, the sharp freezer is a room usually much smaller than the cold storage rooms, preferably located so that its walls adjoin other cold rooms rather than outside walls, with doors opening through anterooms, so that cold air cannot circulate with the outside. The refrigeration pipes are arranged in banks of shelves, vertically on 8, 10, or

12 inch centers, horizontally on 4, 6, or 8 inch centers, these dimensions depending on the chosen ratio of piping, on the size of fish or pans, etc.

Loading Fish into the Sharp Freezer.—Panned fish are placed on the pipes. In public freezers, the first and last pan of each lot may be marked with a slip of paper to indicate the lot. Where large fish, such as salmon, halibut, sturgeon, swordfish, etc., are frozen the shelves must be farther apart and be covered with sheets of 14-gauge galvanized iron. The fish are laid on this, or else, as is done in some places, the fish are laid on the floor, or on slatwork along the floor. In some well-systemized plants, two or three men are assigned to a particular room at each loading, a record is kept and they are held personally responsible for putting in the fish straight. Where large fish are thus loaded in, they must not overlap so much as to freeze together inseparably.

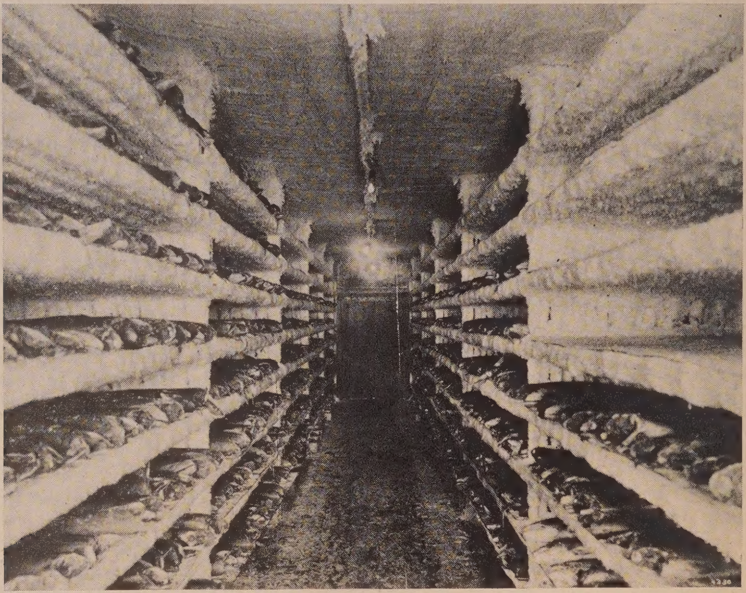
In most of the freezers, including all the smaller ones, the fish for the freezers are placed on small trucks and thus conveyed to the freezers. In a few large freezers, roller conveyors are used to convey the pans by gravity to the sharp freezer. A narrow hole through a wall or door serves to admit the pans. A section of the conveyor runs between the banks of coils. Men working in the sharp freezer take the pans from the conveyor and place them on the shelves.

Temperature Maintained in the Sharp Freezers.—In large sharp freezers and especially where brine is circulated through the pipes, there is a comparatively large reserve of refrigeration in the brine, pipes, and air. Consequently a comparatively large quantity of fish can be placed in the rooms without excessive rise in temperature. Since the rate of extraction of heat from a body is proportional to the difference in temperature between it and its surroundings, it is evident that fish will freeze more rapidly if placed in a cold room than they will if placed in a room warm at the start. The temperatures often available in such large rooms—say rooms of 60,000 lbs. capacity—range from 0° to —12° F., which not only makes possible a relatively well preserved fish, but also shortens the time of freezing.

The small individual freezer is, however, more popular, especially where direct expansion is employed. There are usually several such rooms, side by side, each of a capacity of from 12,500 to 30,000 pounds. While such a room is being filled with a large quantity of fish the temperature rises rapidly to 15 to 35° F., though lower temperatures often prevail on completion of loading. When the room is filled, the door is closed and the expansion valve opened. The temperature gradually falls as the heat is extracted. The lot is judged to be frozen when the room has reached a temperature of, say, — 10° F. This figure not only varies from freezer to freezer, but in any particular freezer is subject to change with the exigencies of the day's rush. When there is no hurry, the room may be allowed to reach —15 or —20° F., but if the freezer is needed for a fresh lot, the frozen lot may be taken out at 0° F.

The time required to freeze the different species of fish is not in practice so important as it might otherwise appear to be. The filled pans are almost always left in the freezer over night, i.e., 24 hours or less. If the fish freeze in a shorter time than this, no advantage can be taken of the saving because the time for change could fall in the night. Large fish, such as halibut and salmon, are left in the sharp freezer over two nights, i.e., 40 to 48 hours. Very large fish may remain in the freezer 3 or 4 days.

The rate of freezing (i.e., the extraction of heat) is not uniform. When the charge is first put in the room the temperature falls rather rapidly until freezing begins. Then ensues a long period of little change in temperature while the fish are freezing. The third period is of more noticeable lowering of temperature. In plants where ice tanks are cut off during the day, but are making ice at night, the influence of the heavier night load is observable, also, in the sharp freezers.



Courtesy New England Fish Co., Vancouver.

FIG. 103.—Interior of sharp freezer of small individual type, salmon being frozen.

Defrosting the Pipes.—This may be done by warming the room and flooding the pipes with warm liquid ammonia or brine, thus thawing out the ice which adheres to the pipes. Another method is to scrape the pipes with irons having a semicircular recess to fit the pipes. The former wastes refrigeration and is said to be very bad for the fish frozen immediately afterward because of the excessive dehydrating effect on the fish. The latter method of scraping the pipes is said to cause much less tendency to dehydrate the fish, but is rather laborious. In some plants the pipes are defrosted after each freezing; in others only once in from 1 to 2 years. In the latter event covered pans are desirable. It seems permissible to recommend for sharp freezers:

1. Comparatively large rooms—30,000 to 60,000 pounds capacity.
2. Brine circulation rather than direct expansion.
3. The lowest possible temperature obtainable.
4. Conveying pans into the rooms by gravity conveyor.
5. Infrequent defrosting with scrapers.
6. Pans with covers.

4. Glazing.

Various methods have been practiced to prevent the desiccation, rusting and loss of flavor to which frozen fish are subject during the period of storage. Wrapping with impervious paper, glazing, covering with wax or tallow, and freezing in ice blocks have all been tried. The simplest, cheapest and most practicable is glazing, and, if properly done, answers all requirements.

Nature and Purposes of Glazing.—If the fish is, while frozen, dipped into cold water, and withdrawn into the air of a cold room, the adhering film of water freezes, forming a transparent envelope of clear ice surrounding and adhering firmly to the fish. The ice glaze at once brightens the colors of the fish, and prevents all evaporation from the fish as long as it remains intact. It serves to retard rusting, but unless the storage temperature is sufficiently low, cannot altogether prevent it. It also serves, perhaps, to prevent the loss of flavor in fish during storage. Upon close examination it will be found that the ice envelop has many small holes through it, and it is through these that the oil seems to come to the surface of the glaze.

Methods of Applying the Glaze.—Certain facts are necessary to be taken into account for the best glazing. In the first place, the glaze should be uniform. For some reason, for which no good explanation is yet forthcoming, if the water is too cold (32° F.) the glaze will be pebbly. The water is usually from 34° to 38° F., but may be as warm as 50° and still apply a thin but perfect glaze, provided the air of the glazing room is sufficiently cold. A glaze may be applied in a room of air temperature from 28° to 32° F., but in that event, the adhering film of water gives up its heat to the fish, instead of to the surrounding air; since the thinner parts, such as fins, snout and tail have not sufficient heat capacity to freeze the glaze, these parts are not glazed under such conditions. It is far better to do the glazing in a room of sufficiently low air temperature so that the adhering water film, in freezing, gives up its heat at least in part to the air surrounding. When glazing is done in this way the fins, tail and snout are perfectly glazed.

There is some difference of opinion on the question of the proper temperature of the fish at the time of glazing. When the fish comes from the sharp freezer, its temperature may be —10° or —15° F., and is to be stored at, say, 5° F. (or higher). If the glaze is applied while the fish is at —10° or —15° F. on subsequently warming up to 5° in cold storage, it is argued that expansion will crack the glaze.

The cakes of frozen fish are removed from pans by showering the latter, while inverted, with tap water, and a blow with a stick may then be necessary to dislodge the cake. A trough 12 or 14 ft. long by 2 ft.

wide by 12 inches deep containing water then receives the cake at one end. The succeeding cakes push one another along, and are taken out at the other end of the trough. They remain in the water from ½ to 1 minute. In other places, a much shorter trough is employed and a much briefer immersion is practiced. The room, where a separate one is provided for glazing, should be at a temperature of 12° to 15° F. The cakes are then weighed, boxed and stored, or else stored without boxing. In some freezers, a movable glazing trough is taken into the store room and the cakes are glazed and stored immediately.

In the glaze, the fish gain in weight an amount which varies with the number of dips, the temperature of air and water, the duration of dips, and above all, whether the fish are in cakes or not. Cakes of about 30 lbs. dipped once in water at about 34° F., and allowed to remain in the water one minute, take a glaze equal to about 4 to 7% of the weight of the fish.

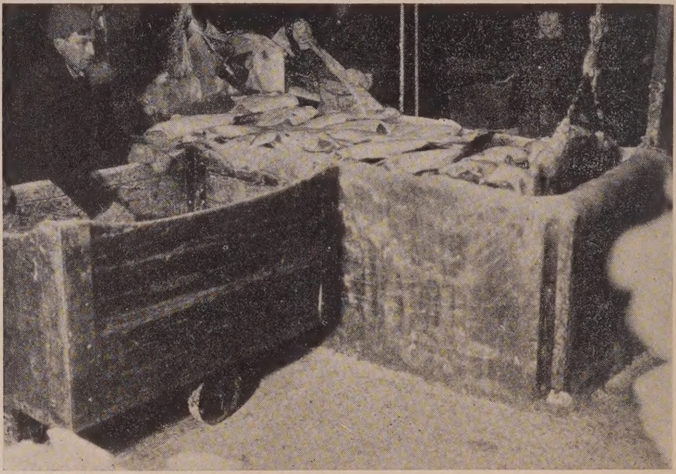


FIG. 104.—Glazing tank for salmon and halibut.

Large fish like halibut and salmon are glazed in an apparatus which consists of a wooden tank and a framework also of wood capable of being lowered into the tank by a windlass, lever, or other such mechanism. The fish are trucked from the sharp freezer to the glazing room, and are put on the frame. The frame is then lowered one, two, three or four times, usually three, each immersion being of only 5 or 10 seconds' duration. The fish are then returned to the same or another truck and conveyed to the storeroom.

An improvement on this method is a concrete tank below the floor level, into which a strong basket of angle-iron and heavy wire gauze is dipped by means of a half-ton electric hoist. The basket is taken to the sharp freezer, loaded, trucked to the glaze room, the contents glazed, and then, still without being emptied, is returned to the truck, conveyed to the storeroom where it is emptied. This method makes it possible to do all operations without repeatedly handling each fish, and also works with larger quantities. In these glazing tanks little attention is paid to the temperature of the water as long as the glaze is not pebbly, or the water too warm to glaze at all. Ice accumulates heavily on these tanks, of course, and must be cleaned off.

When fish are in storage it is sometimes necessary to glaze them repeatedly. If in cakes not boxed, the fish may be readily glazed in a trough brought into the storeroom. Boxed fish may also be immersed in tanks, box and all, and so glazed. Fish not in cakes, and not boxed, may be sprayed with cold water with an air brush or sprayer such as is used for whitewash or for spraying shrubbery and trees. The adhering water freezes quickly. The glaze may be applied as frequently as necessary.

For successful glazing, the following points should be observed:

1. The water should be at a temperature between 34° and 40° F.
2. The temperature of the air, if in a separate glazing room, should be at about 12° or 15° F.
3. A series of dips is better than one prolonged dip.

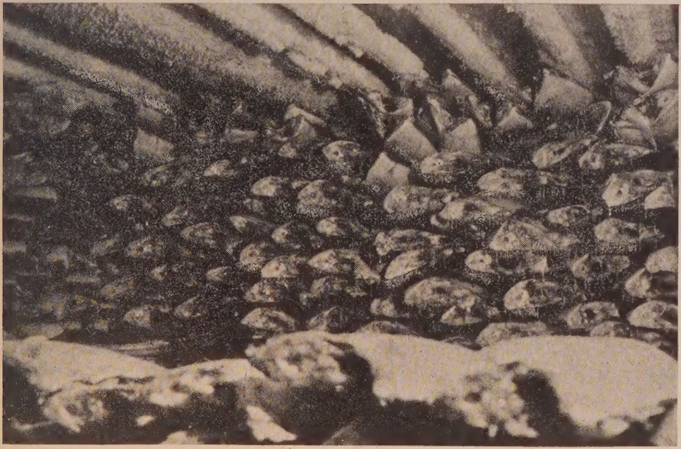


FIG. 105.—Halibut in storage. Glazed with air brush, with formation of icicles.

5. Cold Storage.

If the success in the refrigeration of fish lies more in one part of the process than in any of the others, that part is the storage. Not that conditions are more unfavorable, but that slow changes have so much more time in which to develop and do harm.

Placing Fish in Storage.—Large fish, not boxed, such as salmon or halibut, when in large quantities, are stacked in the rooms. Where large quantities are stored, the room is filled up to the ceiling, in such a way that they do not come quite against the floor and side walls. A slatwork on 2 inch x 4 inch timbers covers the floor, and a similar framework is on the sidewalls, or else a corridor 18 inches to 20 inches wide is left between the walls and the stack of fish. This arrangement permits access for reglazing by spraying. In stacking the fish, tails are inside the pile, the shoulder end outside.

Where fish are boxed, the boxes are stacked in close formation. Salmon and halibut are sometimes wrapped in parchment paper before being boxed. The boxes represent a considerable amount of money tied up and unprofitable. Boxes keep fish well, and retard desiccation and rust; yet fish can be kept as well without boxes. Perhaps in private freezers the fish are less frequently stored in boxes than in public freezers and warehouses. Public warehouses are at a disadvantage in storing fish because they rarely have one lot large enough to fill a room, and the fish must therefore be separated into lots; the consequence of this storing by lots is that much more surface is exposed and rusting and desiccation do much more damage, and the capacity of the storerooms is greatly reduced.

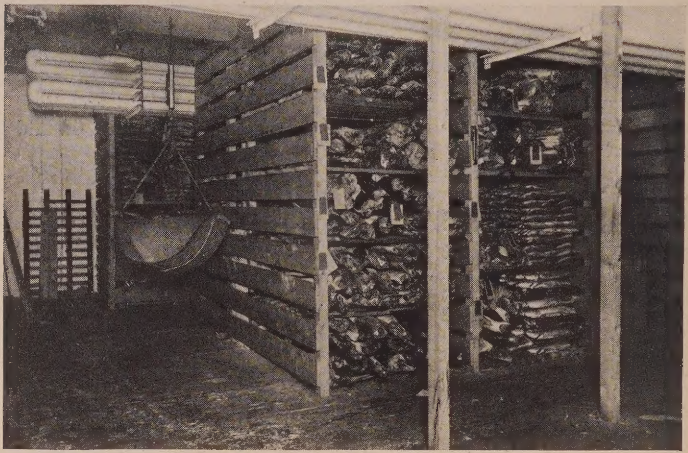


Fig. 106.—Fish in public cold storage. Bins are employed for keeping the lots separate.

Boxes make more difficult reglazing. If boxed fish are to be reglazed, the boxes must be opened or the box dipped entire into a tank of water, either method involving considerable labor, much more than with spraying. Perhaps the most serious objection to storing in boxes is the very much smaller amount of fish that can be stored in the rooms as compared with the storage of unboxed fish.

Where fish are frozen in pans, the cakes may either be boxed or stacked not boxed in the store room. When stored without boxing care must be exercised to avoid breaking tails and snouts in handling the cake. Boxed cakes should be so placed that the cakes stand up edgewise, not flat, so that any cakes that may not be fully frozen can freeze by a circulation of air between them.

Desiccation and Rusting.—The loss of moisture and development of rust are the great enemies of stored frozen fish. The preventives are simple: glazing and low temperatures.

The argument is often made that since low temperatures promote loss of moisture and high temperatures promote rusting, there must be some optimum point where storage is at its best. Some even go so far as to suppose that there is an optimum for each species of fish. This line of reasoning appears to account for the "storage temperatures" recommended as best for different kinds of fish, found in some reference books on refrigeration.

As a matter of fact at any temperature low enough to prevent rust, desiccation will take place rapidly; and at any temperature high enough to retard drying noticeably, fat fish will rapidly rust. The escape from this situation is (1) to prevent desiccation by glazing (assisted by wrapping, if necessary) and (2) to prevent rusting by maintaining a temperature of —5° to 5° F. *The temperature cannot be too low.* A temperature of 10° F. is better than 15° F., but rust will occur; 5° F. is still better; 0° F. is excellent; —5° F. is still better. At these low temperatures very fat salmon, if kept thoroughly glazed, may be kept for months with little or no signs of rust. Of course low temperatures are more expensive to maintain than high; but the difference in cost is made up in the better quality of the stored fish and the diminished losses—at least, numerous high-class freezers find it to their advantage to maintain the temperatures mentioned.

Dry wooden boxes absorb moisture; they should be thoroughly wet before the fish are packed in them for storage. Frequent defrosting of pipes is said to promote drying out of fish. The fish which are exposed on the outside of each lot, especially in proximity to cold pipes, dry out faster. Freshly whitewashed walls promote desiccation.

Fat fish are much more given to rusting than lean fish, and particular precautions should be taken in storing them. Salmon, lake trout, mackerel, etc., should have the coldest room, if one is colder than another. Halibut, whiting, flounders and other leaner fishes can stand a higher temperature, but very low temperatures do not damage them.

There is no cure for rusty fish, once they are rusted. Sometimes, their appearance is improved by taking them from the storage, scrubbing with a stiff brush wet with warm water (about 100° F.), in which some ordinary baking soda is dissolved. The brush should be narrow to reach into crevices. The fish are rinsed in another tank of warm water without soda, returned to the sharp freezer a few hours, reglazed and returned to the cold store. The fish are never as good as they would have been if rusting had not occurred.

Fluctuation of temperature promotes desiccation. Rooms once filled should be molested only for inspection and reglazing; lights should be kept off and the temperature held as low and as constant as possible.

Fish show little tendency to mold in storage, unless the temperature is very high. Therefore dehumidifiers, air washers, ozonizers, etc., find little use in fish freezers. Neither does ice stored in the rooms show any beneficial effects in preventing drying.

Fish "in the round" (i.e., as they come from the water, not gutted and heads on) keep better, rust less, and in general are more suited to freezing and storage than dressed fish. This point does not seem to have been investigated sufficiently, however, and a suspension of judgment may be justified until further research work is carried out.

For successful storage, the following points should be observed:

(1) Fish should be thoroughly covered with a uniform glaze before storage, and glazing should be repeated as often as necessary by dipping or spraying.
(2) The storage temperature should be +5° F. or lower for fat fish, and is preferable for any fish. Temperatures as high as 10 are permissible for leaner fish and for a limited time. The temperature cannot be too low.
(3) The temperature in the cold storage rooms should be held constant, lights cut off, and doors kept closed.
(4) Unless circumstances make necessary, fish should not be butchered for freezing, but should be frozen and stored "round." If stored gutted, the glaze should be perfect, and the temperature held very low to prevent rust.

Packing, Shipment, Defrosting, Cooking.

Fish that were boxed before storage may be shipped as they are. Those that have not been boxed must be boxed before shipment. Before being boxed, any culling for size should be done. Some shippers first wrap the fish in parchment paper, which practice somewhat retards defrosting, and rust, and makes a better appearance of the packages. Boxes should be filled as full as possible to prevent abrasion by moving around. No ice is put in the boxes. About four-fifths as many pounds of small fish can be packed in a box when individually frozen as when frozen in cakes.

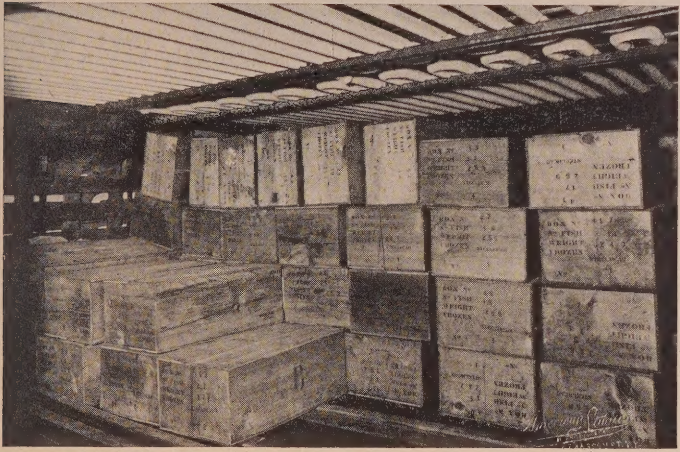
Winter caught fish (fish that have been caught in very cold weather, principally in Canadian lakes, and allowed to freeze in the cold air on the ice where they are caught) are often packed in snow. This protects them against damage in shipment, and prevents desiccation. While the fish are in the snow, however, they are not so readily seen and judged for quality.

For railroad transportation, refrigerator cars are used, with bunkers at either end. These bunkers fill from the top of the car outside. The cars are usually from 8 ft. to 8 ft. 5 in. wide, 29 ft. to 34 ft. long and 6 ft. 5 in. to 7 ft. 7 in. high. The bunkers contain from 6000 to 7500 pounds of ice each, or from 12,000 to 15,000 pounds for the car. Some cars are passenger equipped (i.e., air line equipment for coupling in passenger trains).

For filling the bunkers, the ice is crushed and salt mixed with it. In some places the salt is dumped on top of the ice, but it is considered better practice to mix the salt and ice before filling the bunkers. The amount of ice varies: In winter around 8 to 10 pounds of salt to each 100 pounds of ice; in spring 12, and in summer 15 pounds, are commonly used. It is, however, more difficult to ship frozen fish in warm weather, because of an unavoidable amount of defrosting on the upper tiers of boxes.

Ships equipped for refrigeration have been used for transporting frozen fish.[5] The holds are insulated with cork or lith, and are piped, like ordinary cold storage rooms; the temperatures and other conditions maintained in these holds make them compare in every way with the cold storage rooms in plants on land, and the fish keep in the same way therein.

Defrosting.—Authorities differ much in opinion as to the best method of defrosting or thawing out frozen fish. Reasoning that the water from the ice crystals that have separated from the cell substances can be reabsorbed, some investigators recommend a slow defrosting in a refrigerator, or ice cold water. Fresh water soaks into the fish, swells the meat and blanches the colors. A refrigerator is slow. Bruna, a French chef,[6] recommends no defrosting at all; he puts the frozen fish (salmon) directly into boiling water. The writer has broiled brine frozen Spanish mackerel directly on the grill without defrosting, with excellent results, but there are well known differences between the tissues of brine frozen



Courtesy Elder Steel Steamship Co.

FIG. 107.—Cold storage hold of refrigerator ship, boxed salmon being shipped. S.S. "Neponset."

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[5] See Fisheries Service Bull., Bureau Fisheries, No. 82, March 1, 1922, 5, for description of such a ship, and comparison of rates with those by train.

[6] Cookery of Refrigerated Foods (French). Association Française du Froid. Paris, 1919.

fish and that of air frozen fish. At present fish are seldom sold to consumers in the frozen condition.

II. Other Methods of Freezing Fish.

In the method that has just been described in considerable detail, air is the principal medium for conducting the heat away from the fish; that method is practiced extensively all over the North American continent. By it millions of pounds of fish are frozen annually and with much success. The most serious objections to it are the changes which take place in the tissues during the very slow freezing which the fish undergo in the sharp freezing rooms.

As has been shown, when fish freeze slowly the water contained in the muscle plasma and blood separates out and freezes as crystals of pure water ice. The slower the freezing, the larger the crystals. When the fish is defrosted, not only is juice, containing flavoring matters, lost, but the fish spoils much more rapidly in consequence of the damage done to the cellular structures by ice crystals. These changes set a serious limit to the business that can be done in frozen fish. Therefore, the principal steps taken to improve freezing methods aim at securing more rapid freezing.

Brine Freezing.

Brine is a much better conductor of heat than air, and has a much greater specific heat. Therefore, fish immersed in brine of, say, 0° F. will freeze very much faster than in air at the same temperature. Although substances other than salt have been proposed (e.g., glycerin, alcohol, magnesium chloride, etc.), salt is the only substance so far used which answers all the requirements of freezing point, cheapness and palatability. Several methods have been proposed, and others are in the experimental stage.

Dahl's method, known in the United States as the "Frigus" method, was invented by Nekolai Dahl, a fish exporter at Trondhjem, Norway. It consists of (1) mixing salt and crushed ice, forming cold brine; (2) packing the fish in the shipping boxes; (3) pumping the cold brine by means of a centrifugal pump through flexible hoses into the boxes of fish, so that the brine in running over the contained fish, freezes them.

The method of making brine, which is practicable in Norway where ice is cheaper than it is in this country, is rather impracticable here, though it might be suitable for small plants. The serious objection to this method of making brine lies in the fact that the brine accumulates as ice melts, more salt is required, and both brine and refrigeration must be continally thrown away. For these reasons it will probably be necessary to use artificial refrigeration with this method in the United States if it is to be extensively used. Another objection to the method is, obviously, the difficulty in reaching all the fish in a shipping package by means of a stream from a hose. To meet this difficulty, several improvement patents have been taken out. It is, of course, difficult by this method to control operations accurately and to be sure that all fish are frozen through at any particular time.

The advantages of the method are its obvious simplicity and comparatively small cost for installation if ice and salt are used for refrigeration. The process would involve little labor other than packing the fish, feeding blocks of ice into a crusher, and shoveling in the salt.

Ottesen's method—or rather principle—on which he obtained a patent in many countries, consists of immersing the fish, by any convenient means, into brine which, at any particular concentration, is at a corresponding temperature at which pure ice crystals (mush ice) are separating from the brine. This temperature depends on the concentration of the brine. The stronger the brine, the lower the temperature must be, until at a maximum of 21.4% salt a temperature of —6.16° F. is attainable. This is the lowest temperature possible with pure salt brine. It was shown by Ottesen that as long as ice crystals exist in equilibrium with the brine, penetration of the salt into fish is at a minimum, though some salt penetrates even then.

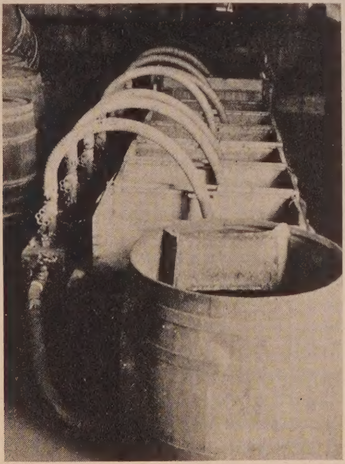

FIG. 108.—Apparatus used in Dahl's method of freezing. Flexible hoses supply the brine to the boxes of fish.

The merit of Ottesen's principle lies entirely in the reduction of penetration of salt to the minimum. The merit of reducing penetration lies principally in (1) the taste, where penetration is excessive, becomes salty, and (2) glazing of a salted fish is more difficult. It may be pointed out here that experiments have shown that brine frozen fish can be perfectly glazed even though the fish were frozen "off the ice curve," i.e. when the brine did not conform to the requirements of temperature and concentration of Ottesen's method. In the matter of taste, unless conditions are extremely unfavorable, salt cannot penetrate sufficiently to be objectionable.

The apparatus used by Ottesen is very simple, consisting of concrete tanks refrigerated by direct expansion coils. Into these tanks the fish are immersed in perforated metal baskets, and the brine is circulated by propellers.

Bull's method consists of panning the fish in specially designed cases or frames, surrounding them with water and freezing the whole into a solid block of ice, containing the fish. This method does not seem to have attained any recognition in practice. Henderson's method, which preceded any of the above, also failed to come into use.

The writer[7] has pointed out that the freezing of fish in brine has not only been proved by repeated investigation to be highly meritorious, but in principle is not patentable (see Hesketh & Marcet, Brit. Pat. 6117, 1889; Douglas and Donald, Brit. Pat. 20,614, 1889; Rouart, Brit. Pat. 5378, 1898; Rappleye, U. S. Pat. 626,771, June 13, 1899. All of these patents have expired). It was stated that the principal problem to be confronted in applying brine freezing to fish commercially was that of designing an apparatus which would get fish frozen in brine expeditiously in large quantities and in merchantable condition. Let us now briefly consider some of the means devised for doing this.

The simplest type of brine freezer is the plan of Rouart, and modifications thereof, which consist of a tank with refrigeration coils mounted at the bottom and a horizontal partition extending partly across the tank above the coils. A propeller circulates the brine, and the fish are immersed in baskets above the partition. Numerous other crude devices that have been tried consist of tanks with pipe coils and propellers of similar general arrangement. An apparatus was devised by the Compagnie d'Alimentation et d'Installations Frigorifiques which consists of a long tank or trough containing the brine chilled by pipes. A belt moving on large revolving drums pushes the fish under the brine at one end, transports them through and delivers them frozen at the other. The brine is filtered during its passage through the pump circuit.

The Fish Preservation Committee of the Food Investigation Board of Great Britain, working at Billingsgate, devised several possible types of brine freezers. One is a drum made of heavy screen or perforated metal revolving in a tank of brine. Means of raising and lowering the level of the brine facilitates loading and unloading the drum. Another method, patented in the United States and elsewhere (Adair and Pique, U. S. Pat. 1,431,328, Oct. 10, 1922), consists of a more complicated mechanism which carries movable drums through a tank of brine, and revolves them at the same time. Several of such drums may be in use, and the machine may be receiving and discharging them continuously. The apparatus seems rather complicated for practical use.

The principal difficulties that are to be encountered in the above devices are: (1) In all of them, tanks of brine are used, carrying great bulk and weight; they are slow to cool in preparation for freezing, and require much salt. Where tanks are used, the business that can be done in a day is severely limited, and so far no tank method has come into widespread use. (2) Since the fish are of specific gravity less than that of brine, they always float; they must therefore be held under the brine, and when forced under, they may curl. (3) The moving parts, coming into contact with brine, rapidly rust and get out of order. (4) They make no provision for a preliminary washing of fish or a washing off of the brine and application of a glaze after the freezing.

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[7] *Bureau Fisheries, Ec. Cir.* 53 (1921).

The writer has designed a plant intended to overcome these and other difficulties. It has been constructed and is, at the present time of writing, undergoing tests to determine its operating characteristics. The essential idea of the method resides in the fact that the fish while suspended on movable bars, are slowly conveyed through a tunnel in which a heavy shower of brine is flowing. The brine flows rapidly over the fish, strikes cooling coils (cast iron radiators), is circulated through a centrifugal pump and back again on the fish. Before striking the brine shower, the fish receive a shower of fresh water to wash them, and after emerging from the shower they receive two or more other showers of water to remove the brine and glaze them. The conveyor consists of two parallel screws in which the hangers rest, the latter traveling as the screws revolve. The whole conveyor system is mounted on a floor above the showers, a narrow slot in this floor being provided to permit the vertical part of the hangers to pass through. By this means is avoided the contact of the mechanical parts with brine. The advantages expected of this method are: (1) Other than hanging the fish, and receiving them from the hangers, all work, including washings and glazing, is mechanically done; (2) it is continuous in operation; (3) by reason of the speed of the flowing brine, and the exposure of the entire surface of the fish, the maximum rate of freezing is reached; (4) the fish, being suspended, freeze perfectly straight and true, in their natural shape, and are individually available; (5) the minimum quantity of brine is required—only what is necessary to cover the suction pipe, fill the pipes and pump and be sprayed is required; this fact is of advantage in that (a) the brine can be discarded frequently without serious waste; (b) the time of initial cooling is very short; (c) the cost of salt is at a minimum; (d) the weight of the plant is small. Only 30 cubic feet of brine is necessary for a plant operating at 1 ton of fish per hour. A further advantage of the method, brought about by the fact that the fish are frozen straight, is that the fish can be dressed and filleted while frozen by ripping out the backbone with a buzz saw. This could not be done with fish curled in freezing.

Brine frozen fish can readily be shipped long distances without ice either by express in wooden boxes, or by parcel post in strawboard containers. These facts put brine frozen fish not only in the class of frozen fish for prolonged storage, but also in a position to compete with iced fresh fish for immediate transportation and consumption.

An objection sometimes raised against brine frozen fish is the difficulty of glazing them. They can readily be glazed if (1) the brine is washed off, and (2) the glazing is done in a cold room. They also take a glaze if they are stored in a cold store some hours before dipping. This method has been practiced for some years by a large fishery concern on the Pacific coast. It has been pointed out[8] that the slight amount of penetration of brine into fish causes a discoloration of blood. While this discoloration does no injury to the wholesomeness of the fish, it may be regarded as undesirable in its effect on the looks of the gills and other red tissues. The effect is worse in gutted than in ungutted fish. But for this effect, brine freezing might be practiced on beef and other red meats.

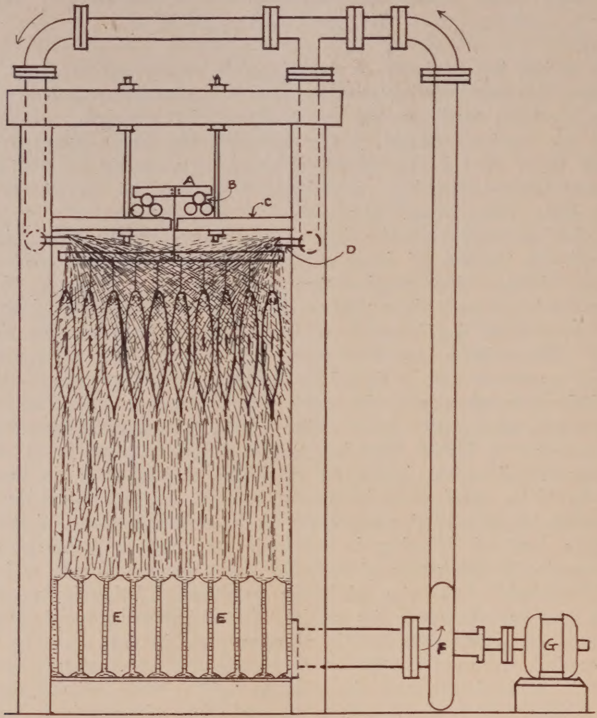

FIG. 109.—Method and apparatus devised by Taylor for brine freezing fish, shown in cross sections. The fish are suspended from a movable bar hanger A, which rides on parallel screws, B; these revolving screws carry the hanger and fish. C is a horizontal partition with slot for the carrier. Brine is sprayed from nozzles, D, strikes and flows over the fish, and over the coils or radiators, E. The refrigerant (ammonia, or calcium chloride brine) flows through these coils or radiators. The salt brine, after being chilled by the radiators, is returned by the centrifugal pump, F, driven by a motor, G. The washing and glazing chambers are at the respective entrance and emergence ends of the tunnel, not shown.

Brine frozen fish can be cooked directly on the grill without preliminary defrosting. The preponderance of experiment and opinion justifies the conclusion that brine frozen fish are not only better than air frozen, immediately after freezing, but are better after long periods of exposure. Unpublished results of experiments in which the writer took part show that fish of one species, frozen by both methods, show differences unanimously adjudged to be in favor of the brine frozen fish by judges who ate the fish without knowledge as to which was brine frozen.

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[8] Petersen, P. W., *Refrigerating Engineering, 9* (1922), 7-9, 15.

Petersen's method of freezing fish[9] arrives at quick freezing by an amplification of the method covered by Hesketh and Marcet,[10] i.e., by packing the fish in cells or containers and immersing the latter into brine. Since the containers exclude the brine from the fish, calcium chloride may be used. The steps in this process are: (1) The fish are packed, or panned, in flat scoops, which fit snugly into the cans; (2) the fish are put by means of the scoop into narrow, deep cans, of such shape as an ordinary pan would be if turned edgewise, only slightly tapered; (3) the cans are hoisted up and let down into a tank of cold calcium chloride brine for the time required to freeze the fish; (4) the cans are hoisted out, dipped in warm water and tilted over, whereupon the cakes of fish slide out, after the fashion of dumping a cake of ice from the can; (5) the cake thus formed is dipped in the usual way to glaze it, and is then stored. The whole process except for filling the pans, which is the essential feature, is like the usual method of making ice in cans. Because the cans are much smaller, and to economize in labor, several of them are built into a frame, the whole frame being hoisted at once.

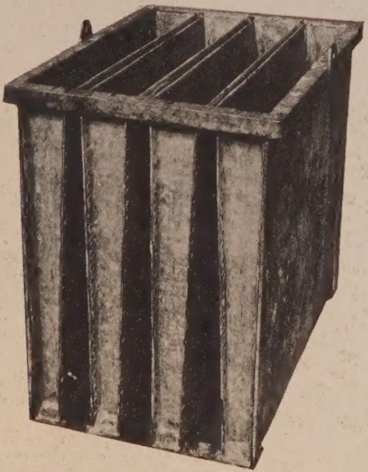

FIG. 110.—Cans used for freezing fish by Petersen's method.

This method should freeze fish rapidly, because the brine may be of very low temperature. Low temperatures (say —25° F.), which are used for this system, are of course more expensive to maintain than higher temperatures; only a fraction of the surface of the fish is exposed to the refrigerating action, and the walls of the can intervene. Thus the disadvantage of diminished surface and intervening can walls are offset by the lower temperatures possible, but the lower temperatures are more expensive of maintenance. The fish, when frozen, are in cakes, and, as such, possess advantages and disadvantages in common with other caked fish. The advantages are easier handling, more compact form and less exposure to desiccation and rust in storage; while the disadvantages are the inaccessibility of individual fish, the flat sides and distortion of form in general.

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[9] U. S. Pat. 1,422,126 (1922).

[10] Brit. Pat. 6117 (1889).

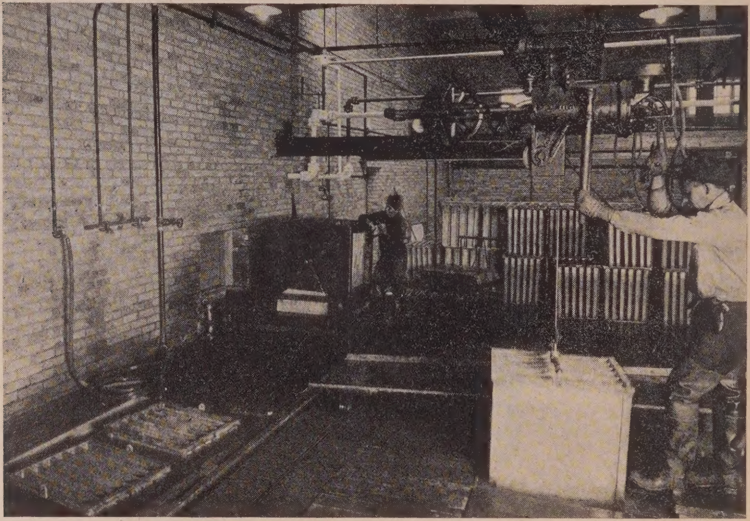

FIG. 111.—Freezing fish by Petersen's method. A set of cans is being lifted from the freezing tank by an electric hoist.

Some provision for separating cakes without defrosting is made by inserting wooden wedges between certain fish at the time of panning. A little strain on the cake after freezing will cause it to break where these wedges are inserted.

Announcement has also been made recently by the same inventor of an adaptation of this method to the individual freezing of fish. For halibut and other flat fishes of that general shape, two rectangular pieces of galvanized sheet iron are crimped together on the two long edges and on one short edge. The remaining side, which is not crimped, is spread open and a pocket formed between the two sheets of metal, more or less corresponding to the shape of a halibut. The fish is slipped into this metal pocket or can, and the whole immersed, up to near the top, in calcium chloride brine at low temperature. For fishes other than flatfishes, whose backs are more or less rounded, the pockets are made by folding over one sheet of metal and crimping together the free edges and one end, leaving the other end open. Here, also, the fish fit more or less into the pocket formed, which are likewise immersed in the brine. One can is required for each fish.

The advantages and disadvantages of this method will be at once apparent to the reader. Rapid freezing is possible, if thin metal and low temperatures are used, and if close contact is maintained between the fish and the can. If this contact is not perfect, as might be the case in many instances, freezing would be retarded. Many cans would be required for operations on a large scale, which, being of irregular shape, might be difficult to handle and store.

It is stated that the fish come out of the cans easily, and are glazed in the usual way by dipping. Fish as small as 2½ pounds are said to be handled satisfactorily, and to freeze, according to the inventor, in one-half the time required for brine freezing.

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Chapter 16.

The Principles of Fish Salting: The Salting of Cod and Other Ground Fish.

Principles of Fish Salting.

The Preservative Action of Salt.

The four means of preserving meats and fish discovered by aboriginal man before he learned to make hieroglyphics on rocks are freezing, drying, smoking and salting. We do not know in which part of the world salt was first used as a preservative for fish, nor can we say how its use was discovered, as the earliest records show that it was already generally used as a preservative both alone and in combination with drying and smoking processes. In the United States the preservation of fish by canning and freezing has recently surpassed that of salting in importance; but, in nearly all other parts of the world, salting is still the most generally used means of fish preservation.

Salt is used in almost all processes of preservation of fish as a condiment, or to remove objectionable taste or odor, or as an auxiliary preservative; but, strictly speaking, by salting of fish is meant that process of preservation in which salt is the chief preservative used. In curing fish by smoking they are always salted more or less. Lightly smoked fish are sometimes heavily salted but, since these fish possess the smoked fish flavor, they are considered as smoked fish.

The principles of preservation of fish and other products by canning in hermetically sealed cans and jars are fairly well understood by the majority of packers. Doubtless this is so because this process of preservation was discovered and perfected by scientists. Many canning factories employ chemists to superintend the manufacture of their products. But even among the well educated owners of large fish salting establishments, there seems to be a total lack of understanding of the chemistry and physics of fish salting. The methods employed in the salteries today were in use hundreds of years ago and have not been modified in any important detail. The application of scientific principles to the handling and curing of meat has accomplished marvels in the meat packing industry. But, partly because of the lack of organization and partly because of prejudice, the fish salters have not taken advantage of the discoveries of modern science. Several researches concerning the principles of fish salting have been carried out in recent years whose results are of tremendous value to the fish salters. The results of these investigations show that slight changes in the present methods of salting will effect great improvements in the quality of the salted product. For several years the salt fish industry of the United States has undergone a steady decline because of increasing competition with the canned and frozen fish trade, and, unless the salters improve the quality of their products, the industry will become one of the minor fishery industries.

Salt does not possess antiseptic properties in the ordinary sense of the word. Nearly all bacteria require some salt for their growth and most of them grow far better in media containing one or two per cent of salt than in similar media devoid of this inorganic substance. Salt preserves fish by extracting water from them. If fish are packed in salt in a barrel the salt soon withdraws enough water from the fish to form sufficient brine to cover them. Simultaneously with the extraction of the water from the fish, salt passes into the tissues of the fish and soon the body juices have become a concentrated salt solution. When sufficient salt has passed in to coagulate all the proteins coagulable by sodium chloride, and when the cells have shrunk because of the loss of a large portion of their water, the inner flesh of the fish loses much of its translucent appearance and sticky feel and, in the words of the salter, is "struck through." The phenomenon of the passage of the salt into and the water out of the fish is an example of osmosis in which the skin and cell membranes act as imperfect semi-permeable membranes which permit the passage of the water out and some salt in, but prevent the passage of the colloidal proteins of the cells. The flow of water through semi-permeable membranes is always from the dilute to the concentrated solution. Thus, when fish are placed in concentrated brine, water passes rapidly out of the cells of the fish through the cell wall into the brine; if the fish are placed in dry salt the moisture on the outside of the fish dissolves some salt forming a concentrated solution which immediately causes the flow of water from the cells of the fish. Salt from the brine slowly finds its way through the cell walls into the protoplasm. Eventually a condition of equilibrium is reached in which the concentration of the solution inside the cells of the fish tissues is the same as that of the brine. When this condition has been reached the salting process is complete and the fish is said to be "thoroughly struck."

Spoilage of fish is brought about chiefly either by autolysis or by bacterial decomposition. Autolysis is the chemical and physical changes which are brought about by enzymes contained in the cells of the fish after its death. It begins almost immediately after death and proceeds most rapidly at a temperature of about 37° C. (that of the human body). The lower the temperature, the more slowly does this action take place. The blood, certain tissues and glands, such as the kidney, contain very active enzymes. The autolytic enzymes are most active under slightly acid conditions; in alkaline media their activity is greatly reduced. During rigor mortis the acidity of the tissues increases decidedly; this change of hydrogen ion concentration causes an acceleration of autolytic decomposition. Enzymes are most active in dilute solution and do not act in the absence of water. Most enzymes are destroyed or rendered inactive by concentrated salt solutions, therefore salting preserves fish from autolytic decomposition. Bacteria are unicellular organisms which when placed in suitable media multiply rapidly and produce enzymes which break down animal tissues and the various organic substances contained in organic matter. Usually the body of the fish contains few bacteria aside from those in the alimentary tract. However, unless great care is used in handling the fish during cleaning and washing many bacteria are introduced into the fish. Bacteria grow rapidly at temperatures between 25-45° C. Below 15° C. most bacteria grow slowly. While many grow readily in media containing as much salt as sea water, if the amount of salt increases much above this point, the water passes out of the cell and it collapses or reverts to the spore form. Thus strong salt solutions prevent bacterial growth.

When fish are killed, autolytic and bacterial decomposition immediately begin. At first but slight changes in the physical appearance of the fish are noted but, if the fish are not chilled, they soon develop a strong odor and taste, the blood loses its brilliant red color and the tissues become soft. When these changes have reached the point where the odor and taste have become objectionable, the fish is said to be spoiled. The presence of more than 4 per cent of salt in the solutions in the tissues of the fish retards both autolytic and bacterial decompositions and, when the amount of salt in the solution in the fish reaches 20 per cent, the decompositions proceed so slowly that there is little danger of spoilage except through prolonged storage at elevated temperatures. During salting of fish, autolysis and bacterial action tend towards the decomposition of the fish while the passage of the salt into the tissues, and the water out into the brine, retard these processes of decomposition. If the fish are placed in brine or salt during cool weather before they become too stale, they "strike through" before they spoil; but if the salting takes place at such elevated temperatures that the decompositions proceed more rapidly than the salting, the fish spoil.

The Composition of Salt.

The composition of the salt used has recently been found by the author [1] to be of great importance not only in affecting the rate of penetration of the salt into the tissues of the fish but also in determining the physical qualities of the product. The chief impurities in commercial salt are calcium salts, magnesium salts, sulphates and organic matter. Sea salts are almost universally used for the salting of fish. The composition of a number of samples collected from various parts of the world are given in Table 2. From these data it is seen that these salts are for the most part high in calcium and magnesium salts and in sulphates. Turk's Island and Trapani salts, which are used in large quantities by the fish salters of the Atlantic Coast, are particularly high in magnesium salts.

Calcium and magnesium salts and all sulphates effect a retardation of the rate of penetration of sodium chloride (salt) into fish during the salting process. This retardation of the rate of salting permits more decomposition of the protein of the fish tissues during the process of salting. Therefore it is important to use nearly pure salt when stale fish are to be salted or when the salting process takes place under adverse conditions such as in warm climates. Calcium salts retard penetration of salt into fish to a greater extent than either magnesium salts or sulphates and are therefore objectionable if present in appreciable amounts. Sulphates are seldom present in sufficient quantities to be objectionable.

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[1] *Bureau Fisheries Rept.*, 1919, Appendix 5; also Doc. 884 (1920).

Calcium and magnesium salts present as impurities in salt used for the salting of fish affect the color and firmness of the product to a remarkable extent. Fish salted with pure salt are soft, flabby and of a light yellow or cream color. Such fish are easily freshened and when cooked closely resemble fresh fish; they possess few of the qualities commonly associated with salted fish. The presence of as small an amount as one per cent of calcium or magnesium in salt causes a remarkable whitening and stiffening of the flesh. Salts of both of these metals give a strong, bitter taste, characteristic of commercial salted fish. By varying the proportion of calcium chloride in common salt from 0 to 5 per cent, salted fish can be prepared of any desired shade of color from yellow to snowy, chalky whiteness. This should be of considerable value to the fish salter, for it enables him to control the color and character of his product. Salt containing as much as 2 per cent of calcium as calcium chloride produces very stiff, brittle fish quite unlike fresh fish; a like amount of magnesium chloride or sulphate produces a similar though slightly lesser effect. Lesser degrees of stiffness and brittleness may be obtained by using salts containing smaller amounts of these impurities. Insufficient work has been done to indicate the reason for the stiffening and whitening of fish by calcium and magnesium salts. Taylor [2] has advanced the theory that the calcium coagulates the protein. Doubtless the bitter taste of fish salted with impure salt is caused by the retention of some of the calcium and magnesium by the freshened fish.

Commercial Methods of Salting Fish.

There are two classes of commercial methods of salting fish in common use to-day: brine-salting and dry-salting. The term dry-salted fish refers to the method of salting and not to the procedure followed in packing or storing fish; it should not be confused with dried, salted fish.

Brine-Salting.—Brine-salting is of relatively little importance commercially compared with dry-salting, as the chief fish that is salted by the former method is the alewife or river herring. Since the details of the salting of this fish are described in the next chapter only the principle of the method will be considered at this point. The cleaned fish are placed in large vats partially filled with concentrated salt solution. A small amount of salt is put on top of the fish floating in the brine. The fish are stirred daily to prevent the brine from becoming too dilute at any one point. The details of practice vary considerably in various sections but the general procedure is about as outlined above.

Dry-Salting.—The exact procedure followed in dry-salting fish depends upon the kind of fish and the custom in the particular locality. But, for a general consideration of the subject the following description is sufficiently detailed: The round, gibbed, beheaded or split fish are washed, and then packed in water-tight containers with an excess of dry salt. The proportion of salt to fish used varies greatly depending upon the kind of fish, the weather and the custom of the fish salter, varying from 10 to 35 per cent of the weight of the fish. The fish are usually rubbed in salt just before packing and each layer of fish is sprinkled with salt. After a few hours sufficient pickle has formed to cover the fish which are not disturbed until they are completely salted, when they are either repacked in fresh pickle or removed and dried.

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[2] *Am. Fisheries Soc. Proc.*, 1920, 120-152; also *Bureau Fisheries Rept.*, 1922, Appendix 2, and Doc. 919 (1922).

Comparative Efficiency of Brine-Salting and Dry-Salting.—There has been much discussion as to the relative value of the two methods. Recently the author [1] conducted extensive investigations concerning their merits. Using the squeteague and the alewife the dry-salt method was found to obtain more rapid penetration of salt into the fish and to inhibit decomposition more quickly. Evidently, in the dry-salting process the brine remains more nearly saturated. This is probably because of the greater surplus and better distribution of the dry salt.

Influence of Methods of Cleaning.

Many of the small fish such as the herring and alewife are not cleaned but are salted round. Such salted fish possess distinctive flavors which are much desired by certain connoisseurs of sea food. Other small fish are cut at the throat and the stomach and intestine are pulled out. All larger fish are always thoroughly cleaned, and are usually beheaded and split down the back. The author's studies concerning the rate of decomposition of fish, cleaned in various ways, during salting under unfavorable conditions, have indicated clearly that it is essential that all blood and viscera be removed if decomposition is to be reduced to a minimum. The amounts of amino acid nitrogen formed during the dry-salting of alewives cleaned in various ways are presented in Table 39. Since amino acids are amoung the end products of protein decomposition the rate of their formation is an excellent index of the rate of protein decomposition.

Because of the tendency of the viscera, blood and various glands to spoil, round fish cannot be salted during warm weather. Scotch cured herring cannot be salted except in cool countries during the fall, winter and spring. Fish free from blood and viscera have a milder, less "fishy" taste than poorly cleaned fish.

The Storage of Salted Fish.

The importance of proper storage conditions for salted fish can hardly be overestimated. This is particularly true of mackerel, herring and alewives. Under the present methods of storage a very large proportion of salted fish reach the retail dealers in poor condition. The merchant must either sell the fish immediately or keep them in refrigerators until his market demands them. Even when the retail dealer disposes of his salted fish quickly, a large percentage of the fish must be sold at a low price because of rust or taint.

No figures are available which show what proportion of the salted fish are culled out before they reach the consumer. A representative of one of the largest salt fish packing establishments in this country stated that the loss of mackerel during repacking because of rusting alone varied from

TABLE* 39

DEVELOPMENT OF AMINO ACID NITROGEN IN FISH CLEANED IN VARIOUS WAYS

(Fish salted four hours after capture, with Diamond Flake salt containing 99.78 per cent sodium chloride; salting period, nine days.)

Method of Cleaning	Average Temperature of Salting	Amino Acid Nitrogen Formed During Salting Period per Kilo of Fresh Fish	Condition of Fish at End of Period
	° F.	Grams	
No cleaning, salted round	79	0.77	Badly spoiled, bloated
Pipped	79	.63	Spoiled
Head cut off, abdominal cavity split open, viscera, except milt and roe, removed	79	.68	Do.
Cleaned perfectly, milt and roe removed, kidney and membranes scraped out and all blood washed out	79	.37	Excellent condition
No cleaning, salted round	88	1.12	Badly spoiled, bloated
Pipped	88	.76	Badly spoiled
Head cut off, abdominal cavity split open, viscera, except milt and roe, removed	88	.82	Do.
Cleaned perfectly, milt and roe removed, kidney and membranes scraped out and all blood washed out	88	.47	Excellent condition

* Tressler, D. K. "Some Considerations Concerning the Salting of Fish," *Bureau Fisheries Rept.*, 1919; also Doc. 884, 1920.

ten to twenty-five per cent depending upon the season. Another fish packing house which does a mail order business placed their loss on account of rusting at twenty-five per cent of the mackerel business. Without doubt the amount of salt mackerel culled out by the wholesale houses and retail stores because of spoilage is very large indeed.

Herring and alewives or river herring are even more difficult to keep than mackerel. Thousands of barrels of herring are dumped overboard annually because of souring and rusting. The writer has seen the entire season's output of some packing houses discarded because of improper storage.

Cod, haddock and other ground fish contain little fat and consequently do not rust; but even their small fat content is sufficient to cause them to turn yellow with age, become rancid and difficult to rehydrate. These fish when stored in boxes often redden and become unfit for consumption because of bacterial growth.

The agencies causing spoilage of salted fish are those which cause spoilage of fresh fish, viz., enzymes and bacteria, and oxidation and hydrolysis. The conditions under which autolysis and bacterial growth occur have already been described. Oxidation and hydrolysis of the fat or oil of fish occur in fresh fish, but, because of the slow speed at which the actions take place, the results of their action are seldom noticed. The rate at which the various fish oils take up oxygen varies considerably. Tuna oil is one of the most active oils in this regard. Oxidation and hydrolysis of fat occur most rapidly in sunlight, in the presence of a free supply of air at high temperatures. These actions therefore take place chiefly on the exposed surface of the fish. The presence or absence of sodium chloride apparently has little influence on the rate of oxidation of oils.

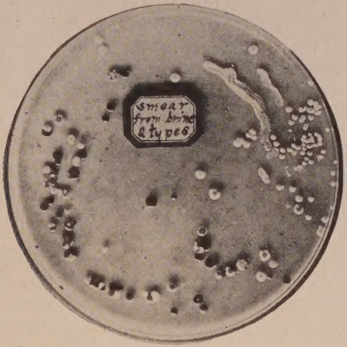

Photo by W. W. Browne.

Fig. 112.—Smear culture of reddening organisms from pickle from salted cod. Note clear red colonies of the bacillus and opaque colonies of the pink spirochæte, also curious rosette colonies, a mixture of both species.

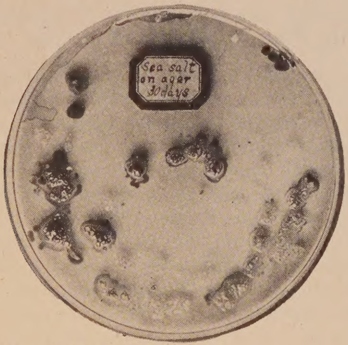

Photo by W. W. Browne.

Fig. 113.—Plate prepared by dropping sea salt on saturated salt fish agar. Note red growth around salt crystals.

Because of the danger of oxidation and hydrolysis of fat and consequent rancidity, fatty fish must be stored in the absence of air if possible.

On this account mackerel, herring and alewives are usually kept under strong brines in cool storehouses.

While salting reduces the rate of autolysis to a slight fraction of its original speed, it does not completely stop enzyme action. The autolytic decomposition of salted flesh of fish is so slow under proper storage conditions that the fish will remain in good condition for at least two years. Blood and viscera rapidly decompose in salted fish if the temperature is permitted to rise above 20° C. Great care must therefore be taken to keep cool Scotch cured herring, and other round or partially cleaned, salted fish.

The storage of cod, haddock and other ground fish is a very serious problem because of reddening, and the development of rancidity of the surface fat. Cool storage retards both of these actions but in shipping small lots of fish it is difficult to keep them cool. The danger of reddening is largely obviated by "hard-drying," but this grade of cod is not liked by the domestic trade therefore little fish is thus prepared except that for export trade. At least two different species of bacteria produce reddening of cod; one of these is a spirochæte which in colonies is pale pink, the other is a bacillus whose colonies are deep red. These bacteria are particularly resistant to salt and live and grow on moist salt or strong salt solutions. Mixed colonies of these bacteria are often found varying in color from pale pink to deep red as the proportion of the two organisms present vary. The reddening organisms are found on practically all sea salts. Mined salts are free from infection with these undesirable bacteria. But as all fish salting establishments are thoroughly infested with the organisms a change to salts free from these bacteria would not be effective in removing the difficulty unless the plants were thoroughly disinfected simultaneously.

A Method of Salting Fish in Warm Climates.

Until recently the problem of salting fish in warm climates was a very difficult one. Many fishermen have attempted to salt river herring and other fish in Florida commercially but were never successful until certain improvements in salting methods were discovered. The changes in the old commercial methods which were suggested came as a result of a careful consideration of the physical and chemical principles of fish salting and extended researches carried out at the Bureau of Fisheries with the cooperation of the Johns Hopkins University, and many commercial fish-salting establishments. The solution of this problem is a matter of great economic importance as it permits the cheap preservation of large quantities of fish in Florida, southern California, Brazil, and many other tropical and semi-tropical regions. The researches upon which the process is based and the improved methods have been described by the author[1] and Taylor.[3]

The cardinal points of the process are outlined below:

After capture the fish should be iced. The fish should not be forked, walked on, nor packed deep in boats, boxes or barrels, and care should be taken to prevent crushing or bruising by chunks of ice.

All viscera and blood must be removed in cleaning. This point is most important as the blood remaining in fish will sour if the average temperature is above 20° C., whereas fresh fish free from blood can be salted at 33° C. or higher. After cleaning it is well to remove the last traces of blood by washing with ice water for a half hour or longer.

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[3] *Bureau Fisheries Rept.*, 1921, Appendix 2; also Doc. 903.

All large fish should be split before being salted. An ample quantity (35 lbs. per 100 pounds of fish) of fine dry salt should be used in packing the fish into water-tight containers. No brine should be used and the salt should be of the highest purity obtainable at a reasonable price as appreciable amounts of calcium and magnesium in common salt retard its penetration.

The fish should be rolled in salt prior to packing and a uniform quantity of salt should be sprinkled over each layer. The length of time required for the salting of fish according to the directions given above varies according to the temperature and the size of the fish. Small fish such as the alewives can often be salted or "struck through" in two days.

Fish salted as described above are entirely free from the strong taste of most salted fish as this is given by calcium and magnesium salts retained in the freshened fish, and by the slightly soured blood. Moreover, they are soft and flexible, and freshen quickly, producing a fish resembling fresh fish in many ways. Salt fish, free from blood, keep much better than similar fish containing blood or entrails, and may be stored in much warmer storehouses. The temperature at which such fish may be stored depends upon the species of fish. Mackerel may be stored at 25° C. for several months, but herring will not remain in good condition at so high a temperature. Both of these fishes should be stored under brine. Fresh brine is preferable to that formed during the salting process.

The Salting of Cod and Other Ground Fish.

Location of Industry.

The salt cod industry is the most important salt fish industry in the United States. In 1919, 62,902,037 pounds of salted cod valued at $12,643,357 were prepared; the value of all other salted fish produced was less than 6 million dollars.

The centers of the cod salting industry on the Atlantic Coast are in Gloucester, Massachusetts, and in Portland, Maine, in the United States, and in Fortune Bay and St. Johns, Newfoundland, and Halifax, Lunenberg and Digby, Nova Scotia. The chief cod salting plants on the Pacific coast are in Seattle and Anacortes, Washington; in San Francisco, California; and in Unga, Nome, Sannak, Unimak, Herendeen, Nagai, Popof, Pirate Cove and Sand Point, Alaska.

The salting of cod was one of the earliest Massachusetts industries and even to-day is one of the important industries of that state although many manufacturing industries far exceed it in the value of the annual output. Until 1863 the cod fishing industry was entirely confined to the Atlantic Coast. In that year Captain Mathew Turner caught the first fare of cod in Pacific waters off the Gulf of Tartary. The number of cod caught and salted on the Pacific Coast has steadily increased since that year. At present that industry is of great importance. The increasing importance

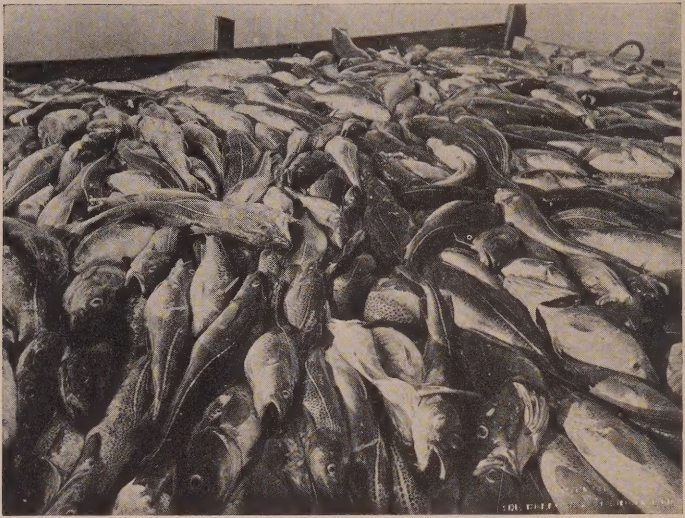

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FIG. 114.—Scow load of freshly caught cod.

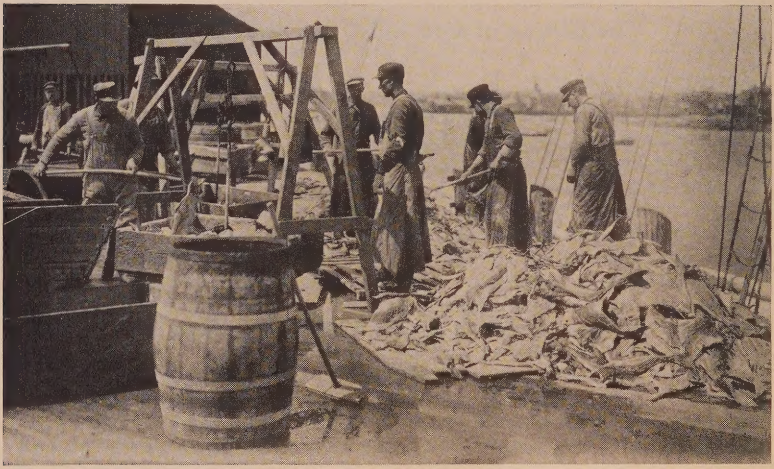


FIG. 115.—Sorting and weighing cod salted on board a schooner at Gloucester, Mass.

of the fresh and frozen fish business because of the more general use of refrigeration and cold storage has caused a great decline in the New England salted fish industry. Some cod are now being canned and perhaps later the canned cod industry may rival the salmon canning business.

Methods of the New England Industry.

Although some cod caught at great distances from market are salted on board the schooner, the bulk of the catch is iced and brought to Boston or Portland, and, if the demand for fresh fish is slack, the fish are sold to the large fish salting firms in Gloucester or Portland. Cod are caught chiefly on hand lines and trawl lines although a few are caught with haddock in the otter-trawl nets. Each day's catch is partially cleaned, the entrails and gills are removed, and the fish are packed in the hold with cracked ice. The amount of ice used depends upon the weather and the probable duration of the trip. In winter no ice is used, but in summer large quantities must be used on the longer trips.

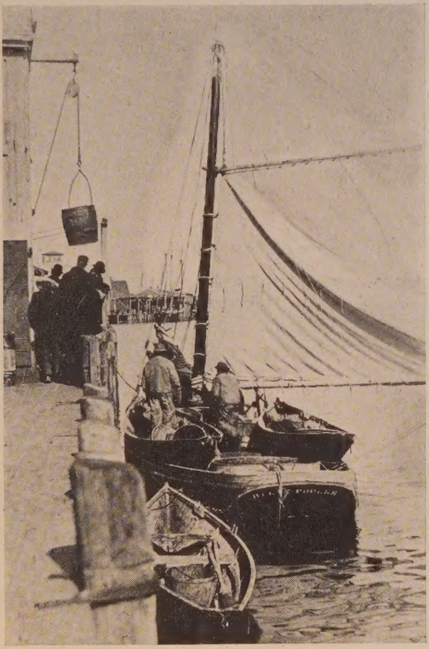


Fig. 116.—Unloading cod at fish salting plant at Gloucester, Mass.

When the schooner arrives at the wharf the fish are pitched into baskets holding about two bushels which are hauled up out of the hold and emptied on the dock where the fish are sorted into three sizes, large, medium, and small (snappers or scrod). They are pitched into racks hanging on large scales. In all cases the pitching is done by means of short-tined pitchforks called pews, similar to those used in handling hay. After weighing the fish are pewed into carts in which they are hauled to the splitting tables, which are located nearby, where they are dumped on the floor. Next the cod are pewed into racks near workmen called "headers" who break the heads off. The fish are passed on to the "splitters" at the other end of the tables. The "splitters" split open the fish and cut out about two-thirds of the backbone, that part from the head to the lower end of the abdominal cavity. The backbones and heads are thrown into barrels and are collected by the glue or fertilizer manufacturer. The fish are tossed into large vats or tanks of sea water; this washes them free from blood and dirt. They are allowed to remain in the vats from 5 minutes to 2 hours, depending upon the number and energy of the boys who scoop the fish out of the vats with small dip nets or forks into carts and haul them to the salters.

Salting.

Butt Method.—In summer all of the fish must be salted in butts or other water-tight containers but in winter when it is cold they are often salted in kenches. A butt is a large barrel, formerly a molasses hogshead, and is about 3 feet in diameter and 4 feet high. The salters throw the cod face or flesh side up into the butts and sprinkle salt uniformly over each layer. When Turk's Island salt is used, 6.5 to 7 bushels of salt are required for each butt of fish. If finer salt is used, a slightly larger quantity is often added, and in hot weather more salt is required. The fish are piled high above the top of the butt, and the last few layers which are exposed are placed backs up. A pile of salt is placed on top of the

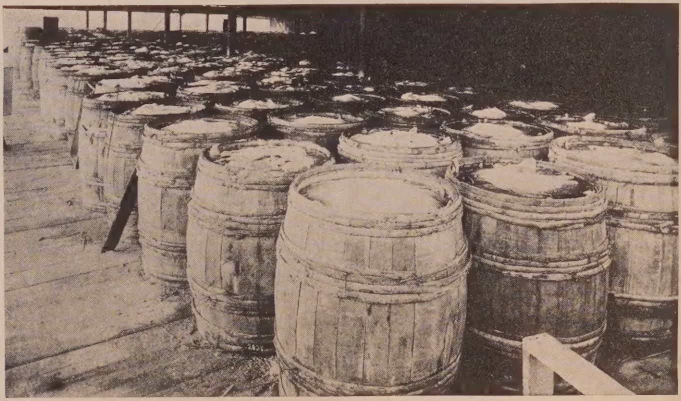


FIG. 117.—Salted cod in butts.

fish. The salt and fish settle slowly and within a day or two sink below the top of the butt. After the fish have settled a bushel or more salt is placed on top. About three weeks' time is required for the completion of the salting process.

Kench Method.—During winter or on board of the schooners the cod are often salted in kenches. A kench is a regular pile of fish made by laying them on their backs with napes and tails alternating. A considerable quantity of salt is spread over each layer. The top layer of fish is turned back up. As the salt extracts the water from the fish it runs to the floor and is drained off. Since the fish do not stand in brine it is much more difficult to obtain uniform penetration of salt by the kench method; therefore there is much greater danger of spoilage (souring) by this procedure than by the butt method. About 20 pounds of salt are used on each 100 pounds of fish.

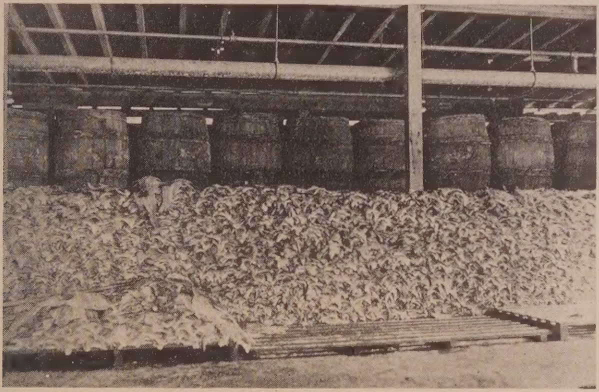


FIG. 118.—Water-horsing salted cod.

Water-Horsing.—When the fish are to be dried, they are removed from butts or kenches and washed with sea water or brine to remove any objectionable slime, and hauled in two-wheeled carts to a building or room having a good concrete floor. Here they are kenched on frames about 8 inches above the floor. Weights of various kinds are placed on the kenches to press the surplus of brine out of the cod. The fish drain and slowly dry in the kenches; the longer they remain kenched the less time must they remain on the flakes. Repiling also aids in the drying of the salted fish, but, since considerable labor is expended in this work, usually the cod are not repiled more often than is necessary to prevent their spoilage. The time which the fish remain in the kenches depends chiefly upon the rate at which the cod dry on the flakes. If the weather is rainy and the fish already on the flakes dry slowly, those in kenches must remain there until the flakes are emptied.

Drying on Flakes.—After kenching, the partially dried fish are placed flesh side up on flakes for further drying. A flake is a rack or lattice bed about 3 feet wide constructed of triangular strips about an inch wide nailed about 3 inches apart to a substantial framework. The flakes are built in the open air about 30 inches above a floor. The fish therefore rest on a sharp edge every four inches thus permitting the maximum circulation of air about them. The drying yard or flake yard is often located on the roof of a building, usually that of the fish salting establishment. Drying under proper conditions effects a considerable bleaching of the cod and therefore great care must be taken if the best quality of fish is produced. If the sun is hot, canvas is stretched about three feet above the flake to shut out the direct rays from the sun which cause the fish to become yellow or "sunburned." On unusually hot days, the fish are not placed on flakes. The weather is watched carefully, and when a rainstorm is imminent, the fish are collected in piles and covered with small rectangular boxes with peaked roofs called "flake boxes."

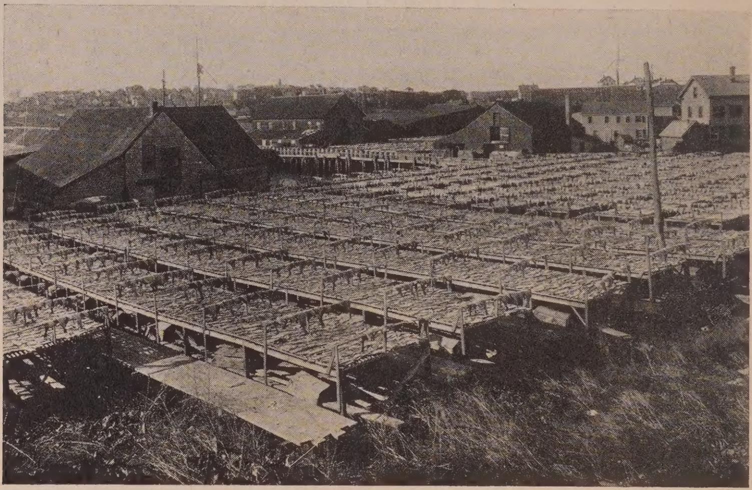


FIG. 119.—Salted cod drying on flakes at Gloucester, Mass.

The time which the fish remain on the flakes depends chiefly upon the weather and the amount of drying and bleaching desired. When there is a strong dry wind two lots may be dried in a single day, but during bad weather a week or more may be required. The degree which the fish are dried depends upon the trade. If they are to be sold in the southern states they must be much drier than if they are to be marketed locally. Fish for export must be dried as completely as possible, flake drying is usually insufficient in the moist New England climate, therefore such fish are dried further in specially constructed driers.

When sufficiently dry the fish are carted to the storehouse where they are kenched until needed for packing, or skinning and boning.

Skinning and Boning.—The fish are sorted as to quality and size. The first quality cod are thick, uniformly white, have no blood-stains, and have a "sweet" odor. If the fish remain long in the sorting room or if the weather is hot and humid, they are sprinkled with fine salt containing 0.4 per cent boric acid to eliminate danger from reddening. After the fish are sorted they are hauled to the "skinning loft" or to the packing rooms. If the cod is to be sold in the south or to the cheaper trade it is heavily doped with salt containing boric acid and tied in bundles which are packed in boxes or drums.

If the fish is to be packed for the northern retail trade it is usually skinned, split and boned and packed in small packages. These operations are carried out in a "skinning loft." The skin is pulled off by skilled workers. The first operation is the removal of the dorsal and ventral fins. The skin is pulled loose at the napes and in toward the middle of the back and then toward the tail. This should not tear the flesh. The tail is cut off, then the fish is turned over and the nape bones removed with a small iron gaff called a "bone hooker." The remaining portion of the back bone is then cut out and the pectoral fins cut off. Other operators then remove the larger bones with small pliers. The yellow and stained portions of the fish are cut away and the cod is cut into strips to fit the boxes being packed. Inasmuch as the large thick "middles" or "steaks" command the highest prices, the larger fish are cut so as to obtain as much of this meat as possible. These middles are usually packed in 5 or 10 pound boxes. The smaller pieces are packed in one and two pound boxes. Some salters pack their product in attractive wooden boxes lined with white parchment paper. Others put the fish in a neatly lithographed carton lined with parchment paper. The white trimmings are made into "fluff" or "fibered codfish" which is usually packed either in cartons with parchment paper lining or in glass jars. The cod skin is sold to fish glue manufacturers

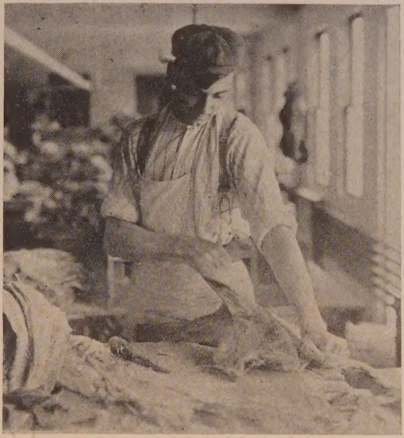
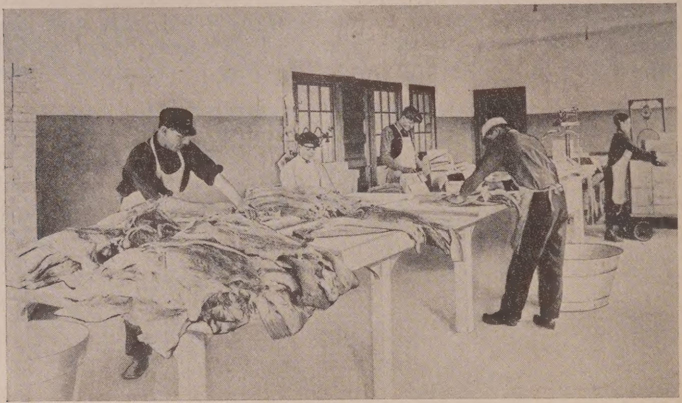


Fig. 120.—Skinning a cod.

and brings an excellent price. The bones and yellow trimmings are also used in the manufacture of glue, but, since they yield a smaller quantity of lower grade glue, are not as valuable.

The better grades of salt cod are "boneless" and "not-a-bone." Boneless contains some of the smaller bones (the small pieces of the fins, and ribs) but "not-a-bone" or "absolutely boneless" contains no bones. It is the practice of nearly all packers of salted cod to sprinkle some fine salt containing 0.4 per cent of boric acid over the fish as it is packed. This aids in the prevention of reddening. But even such preserved fish must be stored at low temperatures if it is to be kept for extended periods. Most packers place their product in cold storage until it is desired for shipment.



Courtesy Frank E. Davis Co.

FIG. 121.—Skinning room where salted cod are skinned, boned and cut into steaks.

Hard-Dried Cod.

Cod prepared especially for export trade is usually hard-dried. This grade of fish is salted in butts in the usual way. After salting, the fish are freshened somewhat by soaking in sea water; the amount of freshening depending upon the particular class of trade for which they are intended. After freshening, the fish are kenched as usual and then placed on the flakes where they are left for a much longer time and become much harder than the regular salted cod. When these fish are removed from the flakes they are placed in driers which may be large racks with chicken wire shelves which have large casters and can therefore be wheeled with ease. These are run into large narrow rooms through which warm air is blown with a powerful fan. The temperature of the air which is blown in is kept above 21° C. (70° F.); if the day is cool the air is sucked through a steam radiator. The length of time which the fish remain in the drier depends upon the temperature, humidity and velocity of the air, and the size of, and amount of moisture in the fish. No determination of the moisture content of the dried fish is made. From time to time they are examined, and if they "ring" when clapped together, they are considered sufficiently dry. Hard-dried cod are sprinkled with fine salt containing some boric acid, and packed in boxes or drums for export. The regular size of drums contains 50, 100, 200, 300, and 448 pounds of fish. When placed in drums several layers of fish are carefully arranged in circular fashion, with the flesh side up and then a layer is placed backs up. The cod are well tamped with a heavy wooden tamper. Other layers are packed and the tamping is repeated. They are packed several inches above the top of the drum; a ratchet or a hydraulic press is necessary to press them down so that the head can be put in place. Comparatively limited quantities of this grade of fish are used by the domestic trade.

Slack-Salted Cod and Pollack.

Fish intended for this grade are usually eviscerated, beheaded and cleaned on board the schooner soon after being caught. They are then lightly salted and piled in kenches in the schooner. When landed at the wharf, they are usually freshened slightly in sea water and then kenched for a short time. They are then dried on the flakes. Slack-salted cod and pollack are sold chiefly in New England.

Haddock, Hake, Pollack, and Cusk.

These fish are often caught on the same trawl lines with the cod, although the most of the haddock are caught in the otter-trawl nets together with some cod and other fish. They are landed at the same wharves, handled in the identical manner, and are usually sorted as to size and species just previous to weighing. The method of curing haddock is identical with that for cod which has been described. Hake, pollack and cusk are salted in nearly the same manner; their average size is much larger and so their heads are chopped off. More of the back bone is cut out as the bones are much larger. A somewhat greater quantity of salt is used with the large fish than is used with the smaller cod. The finished product is much darker than cod, especially in the case of salted pollack, therefore it usually brings a somewhat lower price. For many purposes these fish are the equal if not the superior of salted cod. It is very difficult for the uninitiated to tell them apart by the taste of the cooked fish. These fish are often sold as "salted fish," the particular species not being indicated on the label.

Pacific Coast Industry.

Statistics.

The number of cod salted on the Western coast has increased year by year from 7,100 in 1863 to 3,801,586 in 1915, the latest year in which accurate statistics are available. The complete statistics for that year are given in Table 40.

While the methods in common use on the Pacific Coast resemble those of the Atlantic Coast in the main, there is one important difference—practically all of the cod are cleaned and salted either on board the ship or

TABLE 40

PRODUCTS OF THE COD FISHERIES OF THE PACIFIC COAST IN 1915

Fisheries	Number of Fish	Round Weight	Weight of Salted Cod	Value	Cod Tongues		Cod Oil	
					Weight	Value	Weight	Value
Vessel		Pounds	Pounds		Pounds		Pounds	
Alaska.....	105,500	1,055,000	422,000	$13,926	.....	....	.....	....
Washington	1,374,571	13,745,710	5,498,284	180,934	30,000	$2,090	.....	....
California ..	1,253,500	12,535,000	5,014,000	165,462	7,400	370	.....	....
Total	2,733,571	27,335,710	10,934,284	360,322	37,400	2,460	.....	....
Shore								
Alaska.....	1,068,015	10,680,150	4,265,030	141,246	18,000	900	825	33
Grand total	3,801,586	38,015,860	15,199,314	$501,568	55,400	$3,360	825	$33

at shore salting stations, and later are transported to the home station where the salting process is completed and the fish are dried. The vessel caught cod are not iced, as are those caught on the banks on the Atlantic Coast, but are salted in kenches in the hold of the ship. Those caught by the fishermen near the shore-stations are lightly salted in tanks at this station but are later carried to the home station for bleaching and drying.

The Vessel Fishery.

The fish caught by the fishermen in dories from large vessels on the Pacific banks are not cleaned and salted by the men who catch them but by a special "dress gang" which does little else than handle the fish. This gang consists of a "throater," "header," "splitter," "black skinner," and "idlers." The "throater" grasps the fish by the head with the left hand and by means of a short knife makes a cut on each side of the throat just behind the gills and another slit down the belly to the vent. The fish is passed to the "header" who breaks off the head at the first vertebra and tears out the viscera. The "splitter" continues the split down the belly to near the end of the tail, and removes about three-fifths of the backbone, care being taken not to run the knife deeper into the fish than absolutely necessary. The "black skinner" then rubs off the membrane covering the napes and any spots of blood, and drops the fish into a tub of salt water where they are washed by the "idlers."

The cleaned fish are passed through a chute into the hold where they are salted in kenches. The cod are laid on their backs with napes and tails alternating, with the exception of the top layer which is turned flesh side down. Salt is sprinkled over each layer at the rate of 20 pounds for each 100 pounds of cod, an extra heavy portion being put on where the fish come in contact with partitions or the sides of the vessel. As the brine forms it runs to the bottom of the hold and is pumped out.

Shore-Station Methods.

The shore-stations which are located along the Alaskan coast depend upon the catch of cod on nearby banks for their fish. The fishermen row in dories from the station to the banks each morning and fish with hand lines until noon or until they get a boat load of cod. After the day's catch has been landed the men form as many dress gangs as their numbers will permit and begin cleaning and salting. The fish are dressed and cleaned in much the same way as on board the schooners. The cleaned fish are hauled in large wheelbarrows to the salting house, where they are carefully placed in layers in large tanks. Salt is sprinkled uniformly over each layer. The fish are piled about two feet above the top of the tank to allow for the settling which takes place in a few days. When they have settled below the top of the tank enough layers of fish are added to fill it. About 17 pounds of salt are used to each 100 pounds of fish. The brine in the vats is watched closely, and if it becomes weaker than 87° Sal. (87 per cent saturated), the upper layers of fish are turned backs up and bags of salt are placed on top to strengthen the pickle and press the fish down. The larger tanks in use are square and hold about 4000 medium sized cod, the larger round tanks are somewhat smaller, holding about 3000 fish.

When a station vessel arrives, the pickle is drained off, and the fish are transferred to the hold of the vessel where they are kenched. Very little salt is used in kenching as the fish have been usually well cured.

Curing at Home Station.

When the partially salted cod from a station or fishing vessel are landed at the home station, they are put into long troughs filled with water where they are cleaned with brushes. The fish are then placed in butts in the storage houses, backs down, some salt being sprinkled between each layer. The amount of salt used depends upon the degree and length of previous salting. About a half bushel of salt is placed on top of the fish to strengthen the dilute brine which may come to the surface. The salted fish remain in the butts under cover until orders are received when they are removed, water-horsed and dried on the flakes. The procedure followed in water-horsing and in drying the cod on flakes is the same as that already described as in use in New England.

The dried cod is skinned, boned, cut up and packed in packages in nearly the identical way as on the Atlantic Coast. However, sodium benzoate is used in place of boric acid as a preservative to prevent reddening. It is applied in the same manner as boric acid—mixed with finely ground salt and dusted on by means of a large size salt shaker. Although it is used on fish in the storeroom during warm humid weather, its chief use is in dusting the strips of fish as they are packed into the cartons or boxes. The amount used is not weighed but is dusted over the whole surface. When this preservative is used the package is stamped: "Sprinkled with one-half of 1 per cent soda benzoate. To remove, soak out in fresh water."

Salted Cod Tongues.

Cobb [4] has described the salting of tongues on the Pacific Coast as follows:

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[4] *Bureau Fisheries Rept.,* 1915, Appendix 4; also Doc. 830.

> Cod tongues are saved whenever possible. On the vessel one of the dress gang usually cuts them out, while at the stations some one other than a regular fisherman usually does this work. A cod's tongue is attached to the lower jaw, and when cut out includes all that part of the jaw lying inside the jaw bone. When cutting tongues the operator takes hold of the fish by the back of the head, using the eyes for finger holds; as he lifts the fish by the head its mouth usually falls open, then with his other hand he cuts the tongue loose on the sides with a sharp knife, then cuts loose the lower end along the curving bone forming the back part of the lower jaw. The tongue is then hanging by a thin strip at the forward end of the jaw, from whence it is torn loose by the hand. The tongues are cured loosely in barrels with salt, and after being thoroughly struck are packed in barrels holding 200 pounds, which are headed up, after which a strong brine is added through the bung. They are sold in these barrels or else repacked in half-barrels, pails and kits.

These cod tongues when thoroughly freshened, rolled in cracker crumbs and fried are considered a delicacy by many connoisseurs. Salted cod tongues cannot be kept much over a year as they gradually harden.

Barreled Salt Cod.

There is a small trade in salted cod packed in brine on both coasts. A few haddock are also sold in brine on the Atlantic Coast, but hake, pollack and cusk are seldom marketed in this condition. For this trade the fish are dressed, split, washed and salted in butts in the same manner as those prepared for drying on the flakes. When orders are received, thoroughly salted fish are removed from the butts, cleaned with brushes, and packed flesh side up in tight barrels or half barrels, the fish being bent to follow the curve of the barrel. Salt is placed on the bottom of the barrel and over each layer of fish, about 1 peck of salt being used to each barrel of fish. After heading the barrel, strong brine is added through the bunghole.

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Chapter 17.

Salting of Other Fish

Herring, Alewives, Mackerel, Salmon, Mullet, and Other Fish.

Importance of These Industries—Their Location, Its Significance —A General Consideration of Methods.

In America the salted cod industry overshadows all other salt fish industries, but in the British Isles, Holland, Germany, Norway, Sweden, and Denmark, herring is the most important salt fish product. Salted and smoked herring are staple articles of diet in Europe. For some reason the herring has never attained a corresponding popularity in the United States and Canada. Perhaps this may be accounted for by the enormous variety of large food fishes with which American waters abound. Or it may be that the standard of living of the average person in America is higher than in Europe and, therefore, fresh or canned fish is demanded.

The fish salting industries are located chiefly in Northern Europe, Canada, Newfoundland, the United States, Japan and Siberia. The location of these industries in these countries is largely on account of the climatic conditions and the abundance of fish. Warm countries, such as those of Southern Europe and Brazil, are not well suited for fish salting as such great care must be exercised in all operations if a good product is obtained. In Japan, where meat is scarce and expensive and fish is one of the chief articles of diet, all surplus fish is carefully preserved in some way and, since salting is one of the cheapest means of fish preservation, large quantities are thus conserved. In rugged northern countries with long coast lines such as Scotland and Norway, where farming is attended by many difficulties and is insufficient to support a large population, fishing is one of the principal industries. Here the climatic conditions are ideal for preservation of fish by salting and here the industry has been established for many centuries. A taste has been developed for salted fish and therefore fish canning has not been as generally adopted in these countries as elsewhere.

Cod and other ground fish usually are salted, allowed to develop their own pickle and, after being thoroughly struck, are dried in the open air and stored in the dry condition. These processes have been described in some detail in the preceding chapter. The ground fish contain very little fat, therefore the salted fish may be stored dry. But since fish oil oxidizes and hydrolyzes quickly becoming rancid and causing rusting of the fish, salted fatty fish such as herring, alewives, mackerel, salmon and shad cannot be dried or stored where they are exposed to air.

In the methods of salting fatty fish which are described in this chapter, the fish are kept under brine or away from the air at all times. Herring, salmon, and mackerel are always salted in water-tight containers and are under pickle as soon as the salt extracts sufficient water to form brine enough to cover them. When repacked for market, they are placed in water-tight kegs or barrels which are subsequently filled with brine. Alewives are either salted in the same manner or placed in vats of brine. When packed for market, they are arranged compactly in tight barrels so as to exclude as much air as possible.

Since the general physical and chemical principles of fish salting have been described in the preceding chapter further theoretical consideration of the salting of fatty fish is unnecessary.

Statistics showing the quantity and value of the principal species of fish salted in the United States in 1904, 1909, 1914, and 1919 are given in Table 41.

The Salting of Herring.

The herring salting industry is centered in Scotland, England, Norway, Holland, Denmark, Newfoundland, Nova Scotia, and, in the United States, in Maine and Alaska. Scotch, Norwegian and Dutch cured herring are the best known. In America, the herring usually are salted either according to the Scotch cure or the Norwegian cure process.

Since the herring is caught only in cool regions, little trouble is taken to cure fish which will keep during warm weather. The salters attempt to develop special flavors in their produce. Certain connoisseurs prefer Scotch cured, others Norwegian cured, and others Dutch cured fish. The difference in flavor is due chiefly to the difference in the amounts of blood and viscera remaining in the fish during the salting process. The amount of salt used and the use of old pickle or new brine in packing the fish also influence the flavor of the herring.

Since American methods are modeled so closely after European methods of salting herring, the latter have been considered in detail in the following pages.

American Methods.

Vessel Fishery.—As the herring are removed from the nets, they are placed on deck and water is soused over them to remove loose scales, blood, etc. The fish are then placed in hogshead tubs with about 3 pecks of salt to the barrel of fish scattered among them when they are covered with brine and left standing for 4 or 5 days. After being struck, the fish are packed with backs slanting upwards in market barrels, where they are allowed to settle for a day. Enough salted fish are then added to completely fill the barrels. Three hundred and thirty average-sized herring are required to fill a barrel. After "topping up" with herring, the barrels are headed, filled with strong brine, and stored in the hold. Upon arrival at port, the barrels are examined for leakage and if necessary more brine is added. The barrels are then branded.

TABLE 41

Quantity and Value of Salted Fish Produced in the United States

	1919	1914	1909	1904
Cod				
Pounds	62,902,037	68,456,917	54,302,338	48,757,819
Value	$12,643,357	$5,123,562	$3,248,669	$3,013,320
Herring				
Pounds	14,135,579	21,133,974	21,718,467	15,824,192
Value	$845,629	$641,603	$461,287	$409,223
Mackerel				
Pounds	5,098,700	6,224,313	9,045,469	8,326,566
Value	$1,000,593	$519,727	$740,513	$678,326
Haddock				
Pounds	7,691,146	4,947,286	3,065,156	4,737,975
Value	$815,180	$218,359	$148,191	$213,394
All others				
Pounds	21,883,864	30,386,547	45,038,191	35,929,738
Value	$2,904,641	$1,669,226	$2,719,441	$2,094,748
Total				
Pounds	111,711,326	131,149,037	136,169,621	113,576,290
Value	$18,209,400	$8,172,477	$7,318,101	$6,409,012

If the herring are not of uniform quality they are repacked on shore. Usually the old pickle is used for refilling the barrels, but if it is not clear new brine is used.

Shore Fishery.—The herring on their arrival at the wharves are dumped into tanks or butts of sea water, from which they are removed with a dip net, being rinsed up and down at the same time. The fish are then placed in a "pickling" butt or vat with about 3 pecks of salt scattered among each 200 pounds of fish. A heap of salt is placed on top. After standing for 2 or 3 days the fish are stirred to obtain more uniform salting. After 8 to 10 days, when the fish are thoroughly struck, they are removed and placed on a packing table, whence they are packed tightly in barrels holding 200 pounds, usually with backs slanting upwards, although for certain markets they are placed with bellies inclined upwards. Some salt is scattered over each layer, about a half bushel being used on each barrel. The barrels are then headed and filled with strong brine. The bung is inserted and the barrels are ready for branding.

Some of the herring packed in New England are gibbed before being salted. Eviscerated fish are salted in much the same way as round fish except that they are soaked in sea water for a couple of hours to remove the blood after gibbing. After soaking they are packed in barrels or butts back down, with the stomach cavities filled with salt and a layer of salt sprinkled between the layers of fish. After 8 or 10 days when the fish are thoroughly salted they are removed from the pickle and repacked in the same manner as round herring. In packing, the fish are usually placed fully on their backs although some fishermen place them slightly inclined to one side. The barrels are headed, filled with brine and branded in the same manner as round herring.

The "Scotch Cure" of Herring as Practiced in America.

Formerly but few herring were salted in America according to the accepted Scotch procedure, but in recent years various American merchants have attempted to pack herring by this method and thus supply the American trade which formerly imported about 15,000,000 pounds of herring from Scotland each year. During the war the "Scotch cure" was introduced into Alaska, where temperature conditions are satisfactory.

The peculiar flavor of Scotch-cured herring is caused by the blood which remains in the fish. Blood spoils very easily if the temperature is permitted to rise much above 10° C. Therefore herring cannot be Scotch-cured nor can Scotch-cured herring be kept in warm climates unless they are placed in cold storage.

Only strictly fresh herring free from "red feed" or soil may be cured by this process. Klie[1] states that no ice should be used to keep cool herring intended for this cure.

The fish are not washed but are "pipped" immediately after being unloaded, i.e., the gills and gib (gall, liver, intestines, etc.) are removed by means of a small knife. After gutting, the herring are sorted as to size and content of roe or milt. According to Klie[1] the herring are graded as follows:

Size	Number per 250-Pound Scotch-Style Barrel
Large fulls, not less than 11¼ inches when cured..........	600– 650
Fulls, " " " 10¼ " " "	700– 750
Matfulls, " " " 9¼ " " "	800– 850
Matties, " " " 8½ " " "	950–1000

After sufficient herring have been sorted they are "roused" with salt. This operation is accomplished by placing the fish in a large tub, covering them with fine salt, and thoroughly mixing by hand. This is continued until the entire surface of the gutted herring is evenly covered with salt.

The herring are then packed either in tight 250 pound barrels or 125 pound half barrels. The standard Scotch barrel is made of staves about ¾ inch thick, is 30 inches high, and has a head 17 inches in diameter. The barrel has a capacity of 32 U. S. gallons. The fish are carefully packed in layers backs down, care being taken to keep the rows regular so the various layers are uniform. The herring in the second layer are placed at right angles to those in the first. Enough Liverpool No. 2 fishery salt, half-ground Spanish salt, or half-ground double washed California salt is sprinkled over each layer to almost cover them. More salt is required on fish containing milt or roe but in any case an excess of salt is not added as the completely cured fish should be free from undissolved salt. Some salters of herring allow the herring to make their own pickle, others add some saturated brine immediately after the fish have been packed into barrels. Klie[1] states that this is particularly advisable during warm weather and when curing extra large herring, for it enables the pickle to "strike the bone" immediately from the inside and outside as well.

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[1] *Bureau Fisheries,* Mem. S 58, 1920.

On the first or second day after salting when the herring have settled somewhat, the barrel is filled with herring of the same day's pack. The head is then put in place and the barrel placed on its side and left for 8 or 10 days.

At the end of this period the barrel is again placed on end, head up; the head is removed and a bung-hole is bored in the center of the barrel. The pickle is drained as far down as the bung-hole and poured over the top tiers two or three times. The draining of the pickle causes the herring to settle; therefore the barrel is filled with salted herring of the same day's pack. A very small quantity of salt is sprinkled over each additional layer, except the last, to which no salt is added. When sufficient salted fish have been added to reach to the top of the staves, the head is "jumped" in. After tightening the hoops, the barrel is placed on its side and filled with saturated brine. The bung is put in place and the barrel is branded with the name of packer, trademark, grade and place of cure. The approximate weight of the contents is usually stamped on the bottom.

Herring Salting in Scotland.

The herring fisheries of Scotland are of great importance, the annual catch being about 300,000,000 pounds. Of this about three-fourths are cured, that is, either salted or smoked. In 1921, 457,552 barrels of gutted herring and 9,322 barrels of round herring were cured by salting. The industry is located principally on the Shetland Islands and on the Eastern coast in Peterhead, Frazerburgh, and Wick. A brief description of the principal process of salting herring employed in Scotland follows:

The herring are gutted with a knife, by taking out the gills and stomach. They are then sprinkled with salt and packed in barrels. A layer of salt is placed in the bottom of the barrel then a layer of herring, the fish being laid on their sides. Alternately, a portion of salt and a layer of herring are added until the barrel is full, after which it is headed. After 3 or 4 days the barrel is opened, the surplus of pickle removed, and an additional quantity of herring from the same day's catch is packed in, a quantity of salt is placed on top. After heading up and completely filling with pickle the barrel is ready for branding.

The Norwegian Cure.

Most of the herring caught by the Norwegian fishermen are captured in the fjords in seines, and are kept barred until their stomachs are free from food. Usually the herring are salted on shore close to the place of capture and therefore the fish are quite fresh. The herring are immediately gibbed, which operation has been described by Stevenson[2] in the following way:

> A triangular piece of the throat large enough to admit the heart and pectoral fins to be removed, is cut out by means of scissors made

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[2] *U. S. Fish Comm., Bull. 18* (1898), 443-6.

> for that purpose, or by a small knife (some also use the fingers). This cut should be made deep enough to divide the large blood veins, situated close to the neck bone, in order to remove the blood they contain. Sometimes, also, the gills are removed, especially on the full herring caught in the spring.

As the herring are gibbed they are sorted into from three to five grades. The herring are then packed loosely in new barrels with salt. In packing, the fish are placed slantwise on their backs with the exception of the upper two or three layers which are laid inclined on their backs. Some salt is scattered over each layer; about one-fourth barrel of St. Ybes salt is required for each barrel of herring. Some packers add two gallons of strong brine to each barrel of herring soon after salting, and head up the barrels immediately. Others permit the herring to stand a day before they fill the barrels with pickle. Before the barrels are headed up a layer or two of herring is added to fill up the empty space caused by shrinking and settling.

When the herring arrive at the port of shipment, they are repacked and the barrels refilled with the original pickle. The shrinkage during repacking is about 15 per cent.

Dutch Methods.

The herring fishery of Holland is one of the most important European fisheries. The fishing is conducted by steam and sail vessels which use 2 inch gill nets. The fish are dressed and salted immediately after capture.

Smith[3] has carefully described the procedure of dressing the fish as follows:

> The Dutch method of cleaning herring is similar to the Scotch. Provided with a short knife, attached to the fourth and fifth fingers of the right hand by a string tied to the handle, the fishermen take the herring in the left hand, with the belly up and the head forward, and thrust the knife crosswise directly through the gill cavities, entering the left side and emerging from the right. The edge of the knife being turned upward or outward, the knife is pulled directly through the tissues, cutting and tearing away the gills, branchiostegals, heart, œsophagus, stomach, and often a part of the intestines; the pectoral fins, with the skin and muscle at their base, also come away with the same movement. There is apparently little effort made to remove anything except the gills and pectorals, the other organs coming away incidentally. The men become very expert in cutting, and some of them can handle 1,200 fish per hour (20 per minute).
>
> The removal of the gills and heart results in opening the large blood vessels, and free bleeding ensues; this leaves the flesh pale or white, in contrast with the dark reddish color of the Scotch herring, in which the blood is allowed to clot. It sometimes happens in the Dutch fishery that when there is a large catch the blood has clotted in the last fish handled. The chief and only genuine benefits of cutting as now practiced are the bleeding and the opening of the abdominal cavity to the brine.

After dressing the fish are immediately salted. First they are rolled in salt, then the herring are carefully packed in straight rows with backs down. The fish in each layer are placed at right angles to those of the adjoining layers. Some salt is sprinkled over each layer. A quarter of a barrel of St. Ybes salt is usually required for each barrel of fish. When filled the barrels are headed and stored in the hold until the arrival at port when the catch is unloaded and sold at auction.

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[3] *U. S. Fish Comm., Bull. 22* (1902), 1-16.

The buyer usually repacks the herring before shipping. The fish are emptied into large vats or tanks; the original brine called "blood pickle" is considered much better than freshly made brine and is therefore saved and used for filling the barrels after repacking. The fish are placed in the barrels in the same manner as at sea, and salt is sprinkled over each layer, about 35 pounds of salt being used per 275 pound barrel. The shrinkage in repacking is about 8 per cent. The grade of herring is stenciled on the barrels. The ripe or full fish are branded "VOL" (full); the matties (maatjis) are branded "M"; the spent herring (ijlen) are branded "IJ" or "IJLE." Of each of these there are several qualities designated No. 1, No. 2, etc., and there are several other grades.

The Salting of Alewives.

Location of Industry.

The alewives (*Pomolobus pseudoharengus* and *P. æstivalis*) resemble sea herring in appearance so closely that they are commonly called "herring" or river herring. The mature fish is, however, shorter and much wider than the true herring; moreover it comes up the rivers to spawn early in the spring whereas the true herring is never caught in fresh water. The law now forbids the sale of alewives as herring, hence they are usually sold as river herring.

While many alewives are caught all along the eastern coast of the United States from Florida to Maine the bulk of those salted are packed near Edenton, N. C., Reedville, Va., Havre de Grace, Md., Gloucester, Mass., and Boothbay Harbor, Me. Some are salted on the St. Johns River in Florida but until recently there was considerable danger of spoilage during salting at points as far south as this. In Florida the alewife season opens in January and extends until April. In the Albemarle Sound in North Carolina alewives are caught in March, April and May. At Reedville, Virginia, the season usually opens about April first and reaches its height at the middle of that month. At this point on the Chesapeake, the season is very short and seldom extends far into May. The alewives reach Havre de Grace, Maryland, a few days after the season opens at the lower end of the bay. River herring are caught in Massachusetts and Maine in June and July.

The alewife salting industry is the major fish-salting industry of the Albemarle Sound and of the Chesapeake Bay. In 1918 over 14,000,000 pounds of alewives valued at $401,219 were captured in North Carolina; from these 5,743,846 pounds of salted fish valued at $162,595 were produced. In 1920 the quantity of alewives salted in Maryland by the fishermen was 1,426,300, valued at $62,770, and by dealers 1,957,717 pounds, valued at $69,483. In Virginia, the quantity salted by fishermen in that year was 30,000 pounds, valued at $900, and by dealers 5,738,703 pounds, valued at $158,795. In 1919 the quantity of alewives salted by fishermen in the New England States was 1,265,994 pounds, valued at $56,171.

Dry-Salting Process.

Two methods of curing alewives with dry salt are in common use. One of these resembles the "Scotch cure" of herring and is used in some plants near Havre de Grace, Maryland, and in New England. The other process which involves a thorough cleaning of the fish is the method in use in North Carolina and in Florida.

The latter method, which is more commonly used, is one of the methods especially adapted for use in warm climates, and with a few modifications has been found to be satisfactory even as far south as Florida. At Edenton, N. C., the alewives are usually removed from the traps early in the morning and are transported in small gasoline launches to the salting plants, which are in most cases the property of the fisherman. Here the fish are placed on large tables and cut, that is, the heads are cut off and the bellies are split open. The viscera with the exception of a small length of gut are removed with the head. The cut fish are carefully washed, which is usually accomplished by placing them in a false bottomed tub and washing with a powerful stream of fresh water. This effects a thorough cleaning without additional handling. The alewives are then thoroughly mixed with "ground alum" salt by means of shovels and scooped into butts. No attempt at systematic packing is made. In about 24 hours, the salt extracts sufficient water from the river herring to form enough brine to cover them. After remaining in the butts until they are thoroughly struck, which requires from 8 to 10 days, the fish are spread on the floor to drain and dry as in Virginia and Maryland. After 3 or 4 days, the fish are tightly packed in layers in barrels. About a quart of "Turk's Island" salt is scattered over each layer of fish; no brine is added. These freshly salted alewives are of excellent quality, and, if kept in cold storage, remain in that condition for many months.

Round Fish.—At Havre de Grace, Maryland, a limited quantity of alewives are salted in the "round" or uncut condition. The fish are washed, then tightly packed in barrels covering each layer with dry salt. No brine is added; the fish make their own pickle from the water extracted by the dry salt. When desired for market, the salted alewives are repacked in barrels which are then completely filled with brine, usually that formed during the salting process.

The Brining of Alewives.

About 40 factories prepare salted river herring in the vicinity of Reedville, Virginia. In this locality and also at Havre de Grace and at other points on the Chesapeake, the alewives are salted by immersion in brine, which differs somewhat from the fish salting methods employed in other parts of the world. The fishing season is very short and at its height huge quantities of alewives are caught daily; the methods, therefore, are those which enable the salter to care for the fish in the minimum length of time. Most of the fish are caught in pound or trap nets and are transported by gasoline fishing boats to the factories, which are usually located on some river a few miles from the fishing grounds, and are built at the water's edge partially over water. The fish are usually unloaded onto the wharf by means of large metal buckets hoisted by a crane. The alewives are cut on the wharf by women and children who sever the heads and bellies with one stroke of a sharp knife. The cut fish are thrown into large vats of water and agitated, thus washing off the blood and removing most of the scales. They are then scooped out with dip nets into slat cars, holding about 1200 fish, or other containers, and are transported to the salting vats. The latter are about 10 feet long by 6 feet wide and 24 to 30 inches deep, usually built of 2-inch Virginia pine and hold 12,000 to 15,000 fish. The salting vats are filled one-sixth full of saturated salt solution. As each car of fish is dumped into the brine, a considerable quantity of salt is scattered over them. The alewives are stirred ("roused") daily with large paddles after which some salt is added to strengthen the pickle.

When the fish are thoroughly "struck" or salted, which requires from 7 to 10 days, they are taken from the brine and piled on the draining floor to a depth of from one to four feet according to available space and allowed to drain thoroughly and partially dry. After 4 to 10 days the fish are weighed or counted and packed into barrels. The first layer is placed backs down, the remaining layers backs up. About 2½ pounds of coarse Turk's Island salt are scattered over each layer. The fish are tamped lightly to obtain tight packing. The barrels are filled completely, the last layer extending slightly above the top of the barrel. The head is forced into place thereby lightly compressing the fish. A barrel of "tight-packed" river herring should contain 160 pounds of fish and 40 pounds of salt.

If these salted alewives are to be stored for any considerable length of time they must be placed in cool or cold storage. The bulk of the pack is shipped immediately either to Norfolk or Richmond and held in storage until needed. Even when kept in cold storage, the fish slowly rust and cannot be kept in good condition for more than a year.

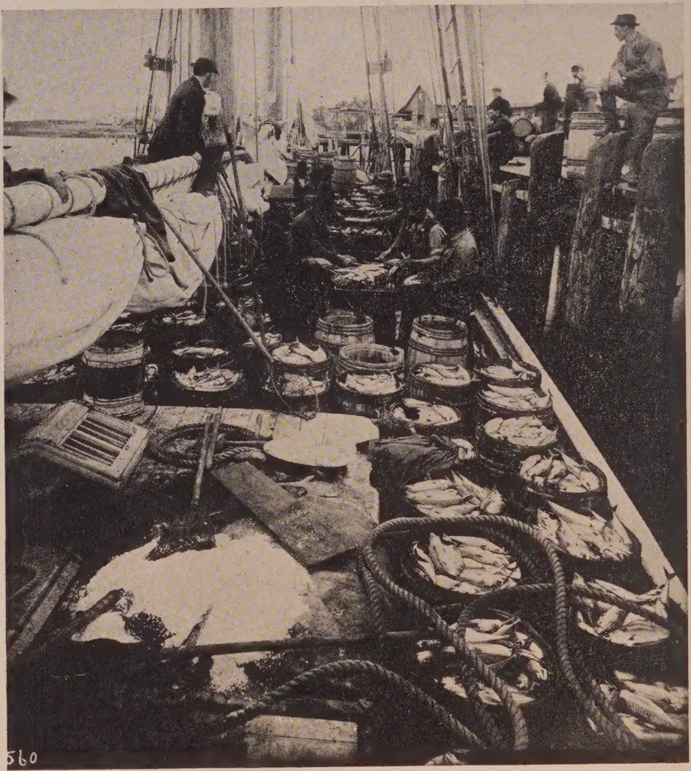
Corned River Herring.

When merely a slight preservation is desired, river herring are salted lightly or "corned" and immediately shipped to the trade. Early in the season in Virginia when the weather is still cool, large quantities are thus prepared and marketed for immediate consumption.

In corning river herring, they are cut and washed according to the procedure just described for the brining process. The fish are placed in the vats of brine but are removed after 12 to 48 hours, the exact time of brining depending upon the temperature and the distance which the corned fish are to be shipped. The slightly salted fish are taken from the vats and spread on the floor and mixed with salt, after which they are packed in sugar barrels and immediately shipped to the trade. Corned fish can be shipped safely only when the temperature is below 15° C.

The Salt Mackerel Industry.

Mackerel is a great favorite among connoisseurs of seafoods, and since the natural supply of this fish is relatively limited the price has risen rapidly in recent years. A much larger proportion of the catch is now sold fresh than formerly was the case. But although the quantity of salted mackerel produced is much less than in former years, since the price has more than doubled, the annual product has increased in value. The statistics for the years 1904, 1909, 1914 and 1919, as given by the Bureau of Census, are presented in Table 41. The industry is centered in Massachusetts and Maine.



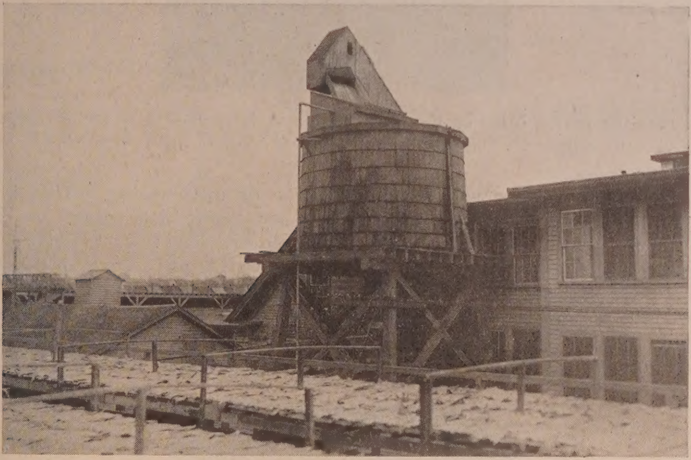
Courtesy Bureau of Fisheries.

FIG. 122.—Cleaning and salting mackerel on board schooner.

The bulk of the mackerel which are salted are those caught by schooners at a considerable distance from port when it is difficult to transport the fish to market and have them fresh on arrival. Most of these fish are caught in purse seines from which they are removed to the deck by means of a large dip net. If the catch is an especially large one, they are placed in a pocket rigged alongside of the vessel, and kept alive until the crew have time to dress and salt them.

Stevenson[4] has carefully described the dressing of mackerel on board the schooners as given below. The procedure has not been changed in any important detail.

> For dressing the fish, the crew is divided into working gangs of three men each, one of whom splits and the other two, known as "gibbers," gill and eviscerate the fish. Each gang of men is provided with a splitting board from 6 to 10 inches wide and with two wooden trays about 3 feet square and 6 inches deep, which are generally supported on the tops of barrels. Some crews, especially in the hand-line fishery, have only two men in each splitting gang, the splitter or some one else getting the barrels, filling them with water, and otherwise aiding the gibber. The splitter with his left hand, which is usually covered with a cotton mitten for protection as well as to prevent the fish from slipping, takes the fish around the center of the body, with the tail toward him, and splits it down the back on the left side of the backbone from the head to the tail, so that it will lie open and flat after the viscera have been removed, the knife being held by the fingers and guided by the thumb sliding along the upper side of the fish. On splitting each fish he tosses it to the tray of the gibber, who, with hands covered with gloves to protect them against the bones, opens the fish with a jerk, causing it to break lengthwise along the lower end of the ribs if it is fat, thus making a crease on each side. He removes the viscera and gills and throws the fish, open and face down, into a barrel partly filled with clean salt water, in which the blood is soaked from the fish, whence they are called "wash barrels." There the fish remain until the splitting is finished, which may be 6 or 8 hours or even longer after the first fish have been split. Then the deck is cleaned up, and the men proceed to salting.
>
> If the men have time they "plow" or ream the fish, making a cut in the abdominal cavity on each side near the backbone, in imitation of the natural cracks or breaks which occur in fat fish, thus giving the fish a fat appearance.



Courtesy Gorton-Pew Fisheries Co.

FIG. 123.—Tank used for the preparation of brine used in repacking mackerel.

After soaking in water the mackerel are emptied from the wash barrels upon the deck and rinsed by throwing buckets of water over them. They are then dipped face down into fine salt such as Liverpool No. 2, and placed in a barrel flesh side down, except that the two or three bottom layers have the flesh side up. Coarse salts are not used as they give a "ragged" appearance.

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[4] *Bureau Fisheries Bull.*, *18* (1898), 431-2.

The barrels of salted mackerel are not disturbed until the vessel arrives in port when they are removed to a cool storehouse. Here they remain until needed for market. From time to time additional brine is added to the barrels to replace any loss by leakage or evaporation. This is important as any exposed fish soon rust and become of little value.

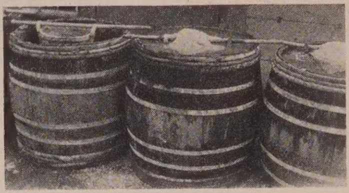
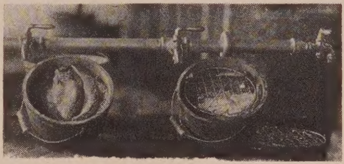


Fig. 124.—Preparing brine by the old method. A large basket of salt is suspended in a butt of water, the salt being replenished as it dissolves.

Before marketing, the salted mackerel are carefully repacked and covered with fresh brine. The tops of the barrels are removed, the brine poured off and discarded, and the fish emptied out, several barrels at a time, into a "culling crib" or box of planed boards with slat bottom and usually about 5 feet long, 3 feet wide, and 8 to 10 inches deep, placed on legs about 3 feet high. The mackerel are sorted into the several grades recognized by the trade and thrown into two weighing tubs with perforated bottoms each holding about 100 pounds, which rest on a beam scale. After weighing, the fish are placed in another box from which they are packed in barrels, kegs or kits, the various grades being kept separate from each other and placed in different packages.



Courtesy Frank E. Davis Co.

Fig. 125.—Mackerel packed in small kits. The fish are held in place by means of the wire frames. Brine is added through pipes leading from the brine tank.

In repacking the mackerel, a small amount of salt is sprinkled on the bottom of the barrel, next two or three layers of fish are placed flesh side up. The remaining layers of fish are packed with the face down. A large handful of salt is sprinkled over each layer of fish, about 35 pounds being used for each 200 pound barrel of mackerel. When filled, the barrel is headed, and then turned on its side; a bunghole is bored in one of the staves and the barrel filled with strong brine (of at least 95° salimeter test). After putting the bung in place, the barrel is branded and is then ready for shipment.

The usual grades recognized by the trade may be defined as follows: Best quality, not mutilated, measuring, when split, not less than 13 inches from the extremity of the head to the fork of the tail, free from taint, rust or damage, are branded as "number one." Mackerel of the same quality as the number one grade except measuring as short as 11 inches are classed as "number two." Second quality mackerel but free from taint or damage and not less than 13 inches in length are graded as "number three, large." Mackerel shorter than 11 inches, yet free from taint or damage, are called either "number three, small" or "number four."

Japanese Methods.

Rutter[5] has briefly described the salting of mackerel in Japan as follows:

> Mackerel are caught in great quantities along the entire coast of Japan proper, and also along the eastern and southern coast of Chosen. Two-thirds of the total catch are used in a fresh state by the Japanese, and the remainder, being cured, is consumed by both the Japanese and Koreans. The quantity cured, however, is not large enough for a wide distribution through the country.
>
> The chief method of curing this fish in Japan is by salting, the amount prepared in this way in 1916 being 1,458,000 kwan (about 12,074,500 pounds), worth about 600,000 yen ($299,100). The method of salting mackerel in Japan is very different from that practiced in Europe and America. According to European and American methods the mackerel is cut along the backbone from the mouth to the end of the tail, while in Japan the head is left untouched, the fish being cut only from the shoulder to the end of the tail. This method of cutting is called "opening the shoulder." The gills and internal organs are then removed, the fish are carefully washed and sprinkled with salt, a convenient number are placed in a box, a basket, or a mat, and are wrapped in a coarse mat to be carried to market.
>
> Sometimes market conditions necessitate keeping the mackerel after they have been salted for a week or so before they are marketed, in which case the salting is done in a large tank or barrel, and more salt is used, the fish and salt being placed in alternate layers. The amount of salt required differs according to the season of the year, the freshness of the fish, the distance of the market, and the length of time the fish will be kept, and is generally between 20 and 40 per cent of the total weight.
>
> **Dry Salting—European and American Methods.**
>
> One other method of curing mackerel in Japan, sufficiently important to be recorded in official statistics, is known as dry-salting, or, more accurately, salting and drying. In this method, after the fish have been sprinkled with salt, they are left overnight and are then dried in the sun. Fish cured in this way have a lower market value, but will keep longer than salted fish. The quantity so prepared in 1916 was 737,341 kwan (6,106,437 pounds), valued at 248,401 yen ($123,828). Other methods used are drying (for use as seasoning), smoking, and canning in oil or vinegar.
>
> Besides the mackerel prepared in the methods above described, mackerel prepared according to the European and American methods have also been produced of late. As this method is still experimental, the output is only about 100 barrels (200 pounds

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[5] *Commerce Repts., 230* (Oct. 1, 1918), 9.

each), just enough to meet the demand of trial sales. If this product should sell well for export at a remunerative price, it would not be difficult to produce from 100,000 to 150,000 barrels annually.

Whiting.

The chief center of the whiting salting industry is Gloucester, Massachusetts. Formerly this fish was considered of little commercial value but during the war when there was a great scarcity of fish, relatively large quantities of this hitherto neglected source of food were eaten fresh, canned and salted. Whiting are caught in traps near Gloucester, and are delivered to the fish salting plants soon after capture. They are scooped into baskets holding about two bushels and hoisted from the dories. Some salt is sprinkled over them as soon as they are dumped on the dock. They are carried to tables where boys cut the heads off just below the gills and split them down the back just at one side of the backbone. The entrails are then scraped out and the fish is thrown into a vat of sea water for a slight washing. After a few minutes the cleaned fish are transferred by means of small scoop nets into carts, and hauled to the salters who pack them either in barrels or butts. The fish are dipped face (cut surface) down in fine salt and then packed backs up into the containers. Some salt is sprinkled over each layer. About a half bushel of salt is required per 32 gallon barrel of fish. After a day or two when the whiting have settled, a half peck of salt is placed on top to strengthen the pickle. When needed for shipment the fish are repacked in barrels. The salted whiting are washed in dilute brine and then placed on conveniently situated tables. The first four or five layers of whiting are packed face up, the remaining layers face down. About a quarter of an inch of salt is placed on each layer of fish; this amount of salt per layer requires about a half bushel of salt per 200-pound barrel. In order to get 200 pounds of the salted fish into a 32-gallon barrel, the fish must be tightly packed; this is sometimes accomplished by tramping with the feet of the workman. A little salt is placed over the top layer of fish, the head is put in place and the barrel turned on its side. A bunghole is bored in one of the staves and the barrel is filled with saturated brine. After the bung is driven in, the barrel is ready for shipment.

The Salting of Salmon.

The American salmon "pickling" industry is located chiefly in Alaska. Its importance is greatly overshadowed by that of the canning industry. The quantity and value of the product has varied greatly from year to year; 56,890 barrels of salmon valued at $1,079,881 were "pickled" in 1919, whereas only 8,110 barrels worth $195,447 were thus preserved in 1919. The mild-curing industry is more generally distributed along the Pacific Coast. Although this industry is of more recent origin than the pickling business it is now rivaling it in importance. Since the larger portion of the mild-cured product was exported to Germany, this industry reached its height in 1913 before the war when a total of 28,282 tierces, approximately 22,640,000 pounds, of salmon were thus cured. In 1919 only 17,184 tierces of mild-cured salmon were prepared.

Mild-Curing.

Cobb[6] has carefully described the preparation of mild-cured salmon as follows:

> In dressing, the head is removed, care being taken to leave as much of the bony structure of the head as possible to assist in holding the side of the hooks when it is being smoked later on; the fish is then split down the belly to the vent, the entrails removed, when a cut is made on either side of the blood clot in the back, and the fish passed to the "washer," who holds the fish on its back in a slot on the table under a spray of water, and removes the membrane of skin which covers the inside of the backbone and inside of which a good deal of thick blood lies, by means of a large spoon or some similar form of scraper. A knife should not be employed. Some curers do not remove the fins at this stage, while others do.
>
> The body is then scored along the sides with a small knife, care being used to cut the skin only; this allows the salt to penetrate more freely and thus assists the process of cure. A specially prepared eccentric wheel is sometimes used for this purpose, which makes a series of small cuts varying from half an inch at the tail to 1½ inches long at the shoulder, and from 2 to 3 inches apart.
>
> The fish is now ready for the splitter, who turns it on its back with the open belly toward him and forces the shoulder down on a sharp-pointed nail, so the fish will not slip during the operation. A cross-cut is first made across the root of the tail to the bone, but no deeper. Then the knife is entered at the vent, immediately above the bone, and a cut, which should go no further back than the middle of the backbone, is drawn down to the crosscut already made. Then raising the lug with his left hand, the splitter enters the knife at the shoulder above the bone, and with one sweep from head to tail, separates the entire side. This is the more easily done if the fins have been previously removed. If the work is perfect, there will be no flesh left on the bone, but a line of fat will show down the center of the side. This improves the appearance of the fish and adds to its value.
>
> In order to remove the bone from the remaining half of the fish, the splitter inserts the knife under the bone, about the vent, and draws down toward the tail; but care must be taken, as before, not to go farther back than the spine. The splitter now takes the fish off the nail, holding it by the lug, his left thumb resting on the upper, or inside of the fish, and his fingers on the lower, or skin side. The tail is now pointing away from the splitter, who enters his knife carefully under the backbone, and with one dextrous outward sweep separates the bone from the fish right down to the root of the tail. When abreast of the crosscut, however, he turns the knife sharply downward, and cuts off the fish the same as on the other side. As with the first half, no flesh should be left adhering to the bone, and the line of fat should show down the center. In other words, the two sides should be exactly alike.
>
> The sides are dipped into cold water in the dress tank, and are then laid, skin side down, on the table with the thin or belly edge toward the front. A man then removes any blood remaining in the veins on the inside of the fish, by pressing it away from him toward the back of the fish, either with his fingers or with a spoon. If the blood is not squeezed out in this way the salt will harden it during the process of curing, and the flesh will become dark in color. The sides are then dipped in a tank of weak brine and crushed ice to give them a final wash, but should on no account be left to soak in the brine. Upon removal, they are again scraped to insure the removal of all blood from the veins.
>
> Great care must be used in handling the newly split sides, as they are very tender and may be easily broken or bruised. In lifting them by the lug or collar bone, the curer should have his fingers to the inside and his thumb to the outer or skin side; otherwise the skin may be broken.
>
> The sides are then taken to the salter, who lays them, skin side down, on a salting table, on which has been dumped a quantity of dairy salt, and gently rubs the flesh with the salt, lifts it up with only such salt as will adhere to it, and places it in the tierce.

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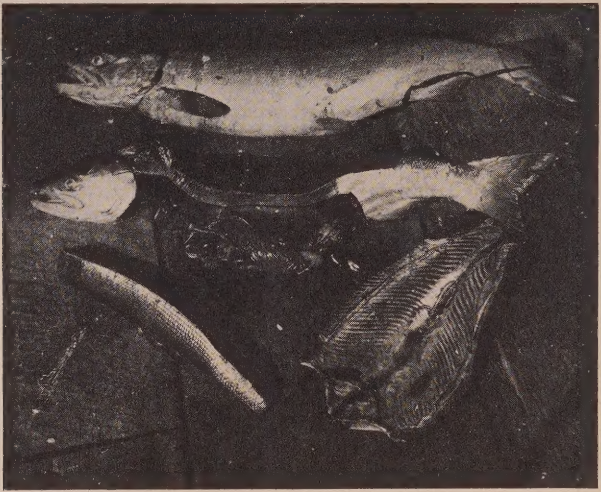
[6] *Bureau Fisheries Rept.*, 1921, Appendix 1; also Doc. 902.

The tierces in which the salmon sides are packed are stout casks made of fir or spruce, bound with six strong galvanized hoops. They contain about 800 pounds of fish, but when full of pickle the gross weight of cask and content is between 1,100 and 1,200 pounds. A plug hole is bored in the head of the tierce.

Two or three handfuls of salt are thrown over the bottom of the tierce, then a layer of salmon sides, skin down, and two or three handfuls of salt are sprinkled over them. In packing two sides of fish, crossed head and tail are packed close to opposite sides of the tierce, the back or thick part of each side being placed close up against the side of the tierce. Other sides of fish are packed from the sides toward the center of the tierce, napes and tails alternately, the back of each side being drawn halfway up and resting on the side already laid. When complete, the layer should be perfectly level, and this depends a good deal on how the last or center piece is laid. Salt is sprinkled between each layer in the manner and quantity noted above and the process continued until the tierce is full. The tiers should be crossed in packing. The top layer should be placed with the skin up and have extra salt put on. From 85 to 100 pounds of salt are used to 800 pounds of fish.



Courtesy Bureau of Fisheries.

Fig. 126.—The method of cutting salmon preparatory to mild-curing.

The tierce is then headed up, after which pickle is poured in until the tierce is quite full. This pickle may be made with the same salt as is used for rousing and sprinkling the fish. Perfectly clear water should be provided and broken ice should be added in liberal quantities, if the weather is warm. Before using, the pickle should be strained through a fine sieve or a clean cloth, to remove froth and sediment. A centigrade salimeter is used by most mild curers. The pickle is made to a strength of at least 90°, but it usually weakens to about 70° during the first 10 days of cure, whereas after repacking it should not readily come below 85°, and it should retain that strength for a long time.

When tierces have been filled with pickle they are rolled inside a cold-storage room, with a temperature of 35° to 38° F., where they may be tiered two tiers high. Very little variation in the temperature is allowable, as it would start the oil or fat in the flesh, allowing it to escape into the brine.

Unless the tierces are kept quite full of pickle the sides of fish are apt to be

> broken when the cask is rolled about. The tierces must be examined frequently to see that they are full of brine, as there are always small leaks, while the staves absorb more or less moisture. Furthermore, if the tierces were allowed to leak, ugly yellow spots would show on the parts of the fish that were left dry. Thus it is of the utmost importance, both during the two or three weeks allowed for pining and also after repacking, to see that they are kept full of pickle. Several gallons of pickle may be absorbed by each cask during the first two or three weeks of cure.
>
> The actual shrinkage during the two or three weeks in which the fish lie in the first packing may be reckoned at 30 per cent. Fat, well-conditioned fish, especially those which are caught in the ocean, shrink less; but poor fish, especially those caught when well on their way to the spawning grounds, shrink more—sometimes up to 35 per cent.
>
> After holding the fish in storage for at least 20 and not more than 90 days, they are taken out of the tierces. Each side of fish should be . . . sponged with a large sponge until all salt and slime are removed.
>
> . . . .
>
> The sides are then weighed and graded accordingly, 6 to 8 pounds, 8 to 10 pounds, and so on being the grades. Sides of 11 pounds and over are called *large* fish, and "L" is marked on the side of the tierce. Some curers grade their sides from 9 to 11 pounds and class them as *medium* and mark them "M"; smaller sides are termed small and marked "S."
>
> After the sides have been graded they should be counted and repacked. . . . In repacking the sides should be replaced as nearly as possible in their original position. . . . No salt is used in repacking, but as soon as the tierce is filled, the head put in, and the air test applied, it is laid on its bilge, and filled up with ice-cold pickle made to a strength of 90° salimeter (90 per cent saturation). . . . They are then put back into cold storage and pickled at the bilge daily for at least a week.

The following marks are placed on the head of each tierce: Initials of packer; initials of place where packed; number of tierce; number of sides in tierce, the tare, and the gross weight (weight of pickle not counted); quality and size of fish.

The chief species which is mild-cured is the king salmon, as it is the only one large enough to fill the requirements of the smokers.

"Pickling."

Cobb[6] has accurately described the pickling of salmon in his classical treatise on the "Pacific Salmon Fisheries."

> In dressing salmon for pickling the head is removed, the fish split along the back, the cut ending with a downward curve on the tail. The viscera and two-thirds of the backbone are removed, and the blood, gurry, and black stomach membrane scraped away. The fish are then thoroughly scrubbed and washed in cold water. They are next placed in pickling butts with about 15 pounds of half-ground salt to every 100 pounds of fish. The fish should be laid in a tier, flesh side up, and the salt well sprinkled over it, repeating until the tank is full. Several boards are then laid across the fish and these are weighted down with large stones in order to keep the fish submerged in the pickle which will form. The fish remain here about one week, the brine being held at about 90°. They are then removed, rubbed clean with a scrub brush, and repacked in market barrels, one sack of salt being used to every three barrels of 200 pounds each. About 40 to 52 red salmon, 25 to 35 coho salmon, 70 to 80 humpback salmon, 10 to 14 king salmon, and 25 to 30 dog salmon are required in packing a barrel of pickled salmon.

Some salmon bellies are also salted and packed in barrels according to the process just described, but in recent years this business has fallen off rapidly as salmon has become more and more expensive.

During the Russo-Japanese War, large quantities of salmon were salted, dried and exported to Japan; but since that time the production of dried salmon has fallen off. In 1919, 212,244 pounds of dried salted salmon valued at $17,601 were produced.

Siberian and Japanese Methods.

The greater part of the salmon catch of Siberia is either pickled or salted and dried. In the Amur region alone in 1915, there were 50,000 barrels of pickled salmon, 6,000,000 salted, dried dog salmon, and about 80,000,000 salted dried humpbacks prepared.

The fish are prepared for salting by splitting down the back so that the sides are held together by the belly. The viscera, gills and roe or milt are removed. After washing the fish are packed in large vats with salt. After a week or two when the fish are thoroughly struck they are repacked in barrels flesh side up except the last two layers which are placed skin side up. After heading the barrels are filled with brine and are ready for market.

The Japanese prepare large quantities of dry-salted salmon in a rather primitive fashion. Cobb[6] has briefly described the process:

> The process consists simply in splitting the fish up the belly, removing the gills and entrails, and then filling the belly with salt. The fish are then placed in rows on matting and covered with salt, and other rows are placed on top of them until the pile is from 8 to 10 feet high, when the entire lot is covered with matting and left for about seven days, after which they are relaid and again covered with salt. For shipping, the fish are packed in mats.

The dry-salted fish are consumed chiefly in Japan.

Mullet.

Because of the difficulties attendant to the salting of fish in warm weather, relatively few have been salted commercially in the Southern States. The mullet is salted in larger quantities in this section than any other fish with the exception of the alewife which is so largely cured in Maryland and Virginia. However, in the Gulf States, the mullet is the only fish salted in large quantities although some channel bass, kingfish, bluefish, squeteague, croakers, perch, sheepshead, Spanish mackerel, striped bass and hogfish are thus preserved.

The mullet salting industry is located chiefly on the western coast of Florida and in North Carolina. The production in 1918 is given below:

	Pounds	Value
North Carolina	315,350	$ 38,341
South Carolina	142,700	14,906
Florida (west coast)	2,453,930	177,974
Alabama	6,000	275
Mississippi	209,498	15,632
Total	3,127,478	$247,128

In addition to this quantity of salted mullet, 100,270 pounds of salted mullet roe valued at $19,422 were produced.

Salted mullet is prepared in two ways, some is salted and sold in brine, the rest is salted in kenches and sold dry.

Brine-Salted Mullet.

The mullet are dressed and cleaned as soon as possible after they are carried ashore. In dressing they are split down the back and underneath the back bone from the head to the tail; the viscera, stomach membrane, and gills are removed. In Florida where the mullet are very large the heads are usually removed and sometimes the backbones. A horizontal gash is sometimes cut in the thick portion of the flesh on the side in which the backbone is left. After dressing, the fish are soaked in clean sea water for about half an hour and the blood and slime washed off. The mullet are then rubbed both inside and out with salt. They are packed in barrels or other tight containers, flesh side up in tiers, some salt being sprinkled over each layer.

After standing for some time or until the fish are thoroughly salted, the mullet are repacked in new barrels, which usually hold 100 pounds of fish. The fish are placed face, or inside of the fish, up, usually the fish of one layer are placed at right angles to the adjoining layers. The barrels are then filled with strong brine of not less than 95 per cent saturation.

Kench-Cured Mullet.

Large quantities of mullet are dry-salted and cured in kenches. This method of salting is especially popular on the west coast of Florida where nearly 2,000,000 pounds are prepared annually.

The fish are dressed as soon as they arrive at the salting plant. The splitting is accomplished in much the same way as in the preparation of salt mackerel; the splitter opening the fish with a knife along the left side of the backbone from the head to the tail. The viscera are removed and the fish is "scored" along the right side which contains the backbone. In some localities the fish are also beheaded. The roe is carefully separated from the viscera and salted separately. After the blood and black stomach membrane adhering to the napes have been scraped off, the fish are washed in clean sea water. Then the fish are rubbed with salt and piled backs downward in kenches 3 or 4 feet high under cover. Salt is sprinkled over each layer. The fish remain in kenches until desired for market when they are packed in boxes or tied in bundles.

Mullet prepared in this fashion is excellent when freshly salted but gradually deteriorates in quality. After 6 months' storage it becomes of decidedly inferior quality.

Miscellaneous Fishes.

In addition to the fishes discussed above there are many others which are salted commercially in the United States in limited quantities often for the local trade. Chief among these are the following: Albacore or tuna, barracuda, bluefish, blue runner or hard tail, bonito, elops or ten pounder, halibut, jewfish, "lingcod," menhaden, pompano, red drum (or redfish), rock bass, rockfish, sablefish, sardines, sea-bass, Spanish mackerel, squeteague, steelhead trout, and yellowtail. Complete statistics relative to the quantity and value of these fishes salted annually in the United States are not available. But the statistics presented in Table 42 relative to the quantities of fishes other than cod, herring, mackerel, salmon, and shad, which were salted in the Pacific Coast states in 1915, show the limited extent of these industries on the Pacific Coast.

Because of lack of space descriptions of the methods used in salting each of these fish cannot be included. The methods are similar to those which have already been given, and usually differ somewhat in various localities but are modifications of the general processes which have been discussed in some detail. The list of selected references contains reference to many articles relative to methods of salting miscellaneous fishes.

TABLE 42

MISCELLANEOUS FISH SALTED IN THE PACIFIC COAST STATES IN 1915 *

	Pounds	Value
Albacore	71,020	$ 3,092
Barracuda	8,000	240
Bonito	8,210	328
Halibut	57,100	3,426
Jewfish	44,998	1,350
"Lingcod"	1,000	20
Rock bass	1,000	40
Rockfishes	3,500	122
Sable fish	212,300	9,728
Sardines	20,000	2,000
Sea bass	3,000	120
Spanish mackerel	6,450	258
Steelhead trout	800	80
Yellowtail	37,158	1,301
Total	474,436	$21,805

* From *Bureau Fisheries,* Doc. 875 (1919).

Salted Dried Yellowtail.

The Japanese cure large quantities of yellowtail in much the same fashion as Europeans and Americans salt and dry cod. The fish are eviscerated and washed and soaked in brine for about two hours. They are then boned and scored with deep longitudinal cuts. The yellowtail are then placed in salt for about a week, after which they are washed and allowed to dry slowly in the shade for about two months. When completely dried the fish are sprinkled with fine salt and wrapped in paper.

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Chapter 18.

The Preservation of Fish by Smoking and Drying.

The Smoking of Fish.

The Industry.

Our savage ancestors, who roamed and hunted in the primeval forests and fished along the seacoast and in the streams, learned through dire necessity to preserve their surplus game and fish for the day of need when no fish or game were to be had. No one knows when man first learned to smoke fish and meat, but we can be certain that it was many thousands of years ago, before the aborigines learned to make signs with charcoal on smooth rocks. Perhaps man learned to smoke fish soon after he discovered how to make fire. When the preservation of fish by salting was discovered, this process was combined with that of drying and smoking, and processes came into common use which have not as yet been modified to any great extent. As fishing became a commercial industry, the scale of operations became greater and greater until now thousands of barrels of fish are smoked at one time in the larger plants. Comparatively few researches have been carried out to improve the quality of the smoked product; the processes are, therefore, much the same as those used by our grandfathers for the preparation of smoked fish.

The American industry has never attained as great importance among the fishery industries as have the fish salting, canning and fresh fish industries of the country; yet the annual value of the product is between 4 and 6 million dollars. The figures collected by the United States Bureau of Census relative to the amount and value of the smoked fish produced in the United States in 1919 and 1914 are given in Table 43.

More fish are smoked in Maine than any other state in the Union. The data relative to the Maine smoked fish industry, collected by the U. S. Bureau of Fisheries, is given in Table 44.

Scotland possesses the greatest smoked fish industry of any country of the world. The quantities of fish smoked in Scotland during the years 1920 and 1921 are given in Table 45. In 1920 the smoked fish produced in Scotland were valued at 3,174,072 pounds sterling or $15,446,621 at normal rates of exchange. This figure makes the smoked fish industry of the United States seem very insignificant indeed, when we consider that the population of Scotland is only about 5,000,000 people.

Smoke-Houses.

Smoke-houses may be of almost any shape and size, from a barrel inverted over a pit to an elaborate brick building with outside furnaces.

TABLE 43

PRODUCTION OF SMOKED FISH IN 1919 AND 1914

	1919	1914
Finnan haddie		
Pounds	6,707,687	4,095,693
Value	$579,000	$328,000
Herring		
Pounds	21,866,205	11,504,126
Value	$1,624,000	$720,000
Salmon		
Pounds	5,574,273	4,248,896
Value	$1,682,000	$639,000
Sturgeon		
Pounds	570,031	511,196
Value	$436,000	$151,000
All other smoked or dried fish		
Pounds	4,644,149	8,353,895
Value	$1,412,000	$921,000
Total		
Pounds	39,362,345	28,713,806
Value	$5,733,000	$2,759,000

The savage tribes smoked fish by hanging them over open camp-fires. When fishing became a commercial industry more and more efficient methods were adopted. Smoke-houses of large size were constructed which were capable of holding thousands of fish. However, little scientific work has been carried out to determine their correct arrangement or proportions. Moreover, very few researches have been conducted to determine the optimum procedure in the smoking process. Because of this, the most important modifications in the smoking processes that have been introduced during the past century were those designed to handle larger quantities of fish more efficiently. The new U. S. Bureau of Fisheries Laboratory in Washington, D. C., which was erected in 1919, contains an experimental smoke-house, but this has not as yet been used.

The style of smoke-house used depends chiefly upon the quantity of fish which are to be smoked at one time. When small quantities of fish are to be smoked, "houses" constructed out of barrels or hogsheads are ordinarily used. After the head is removed, the barrel or hogshead is placed on the ground over a small pit. Twelve or 14 inches of the lower end of one or two of the staves are removed in order to have an opening through which fuel can be placed in the pit. A rod is placed across the top of the hogshead or barrel to support one end of the sticks on which the fish are strung; the other end of the sticks rests on the edge of the barrel. After the smoky fire has been kindled in the pit, coarsely woven cloth or old sacking is thrown over the top of the barrel to hold the smoke in.

The Chinese construct long narrow furnaces, about three feet high and three feet wide, of stone or concrete. These have from 5 to 40 holes about 16 inches in diameter in the top through which the smoke passes into baskets containing fish.

In some smoke-houses the fire boxes are constructed outside of the house containing the fish. These are commonly used in the smoking of river herring or alewives, and are particularly desirable when a cold smoke is needed. In this type, the smoke, generated in the furnaces adjacent to the smoke-house proper, passes up into inclined flues and thence into the chamber in which the fish are hung.

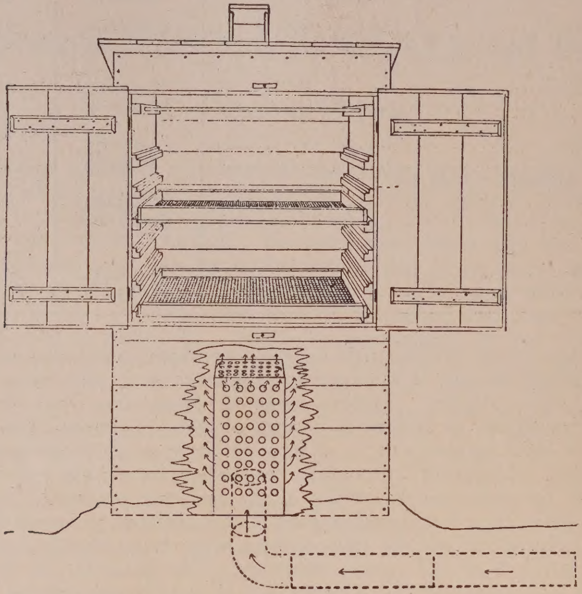

FIG. 127.—Diagram of an experimental smoke-house constructed by the U. S. Bureau of Fisheries.

Hall[1] has described one of the larger smoke-houses used in the smoking of herring in the Passamaquoddy region, Maine, in the following manner:

> The length of the building is 231 feet, 115 feet of which is included in the smoke-house, and 116 feet in sheds of various kinds. The width is 25 feet, the length of posts 16 feet, and the height of the ridge-pole 29 feet. The smoke-house is divided into three compartments, each having 10 "bays" or spaces in which to hang herring, and its capacity is about 45,000 boxes of medium or 60,000 boxes of large herring. It is as large as three smoke-houses of the ordinary size. The smoke-houses have no floors, as the area has to be used for the fires. The interior is arranged with a series of vertical rows of 2-by-4-inch scantlings. The spaces between the rows are termed "bays" and are 38 inches in width. The scantlings in each row are near the ridge-pole and extend horizontally crosswise of the building, each one being placed from 13 to 14 inches below the other, to within 6 or 8 feet of the ground.

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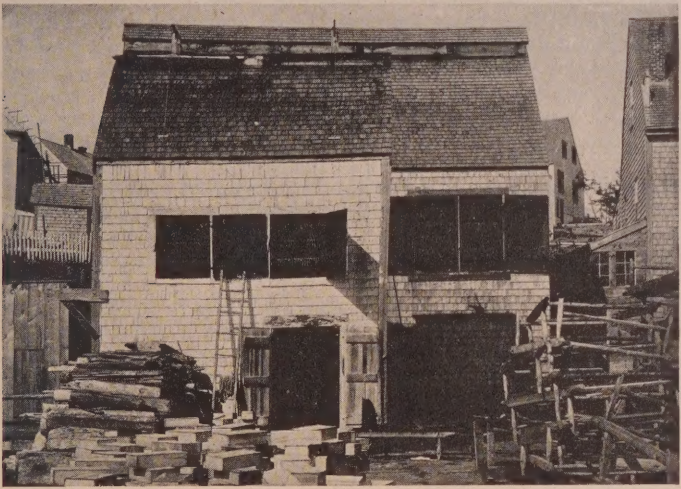
[1] *U. S. Fish Comm. Rept.*, 1896, 454-462.

In smoke-houses of the average size there are usually 10 "bays" and the capacity is about 15,000 boxes of medium or 20,000 boxes of large herring.

Most of the smoke-houses in use in America are smaller than the one described above. The average size herring smoke-house is about 30 feet long, 18 feet wide and about 25 to 30 feet high. Flues are constructed at the top of the house for the escape of the surplus smoke.

Where hot smoking is employed for the curing of the fish, brick ovens with chimneys are usually employed, for a hot fire must be used which might set fire to the ordinary frame smoke-house if it were kindled on the ground.



Courtesy Bureau of Fisheries.

FIG. 128.—A large smoke-house for the smoking of herring at Eastport, Me.

The Production of Smoke.

Hard woods are chiefly used for the production of smoke, since soft woods which contain resins usually give the product a disagreeable taste. Some fish such as the river herring, however, are often smoked with pine smoke. The most important consideration in choosing a wood is to use one which burns slowly and produces a large amount of smoke.

Many hardwoods are used in various parts of the world. The woods commonly employed include the following: oak, hickory, maple, mahogany, alder, beech, white birch, heather, juniper, ash, and poplar. Water-soaked driftwood is often used which may be a mixture of all sorts of wood. White birch is generally preferred for smoking herring in Maine. At Gloucester and Boston, a mixture of oak chips and sawdust is principally used. Oak, poplar, birch and ash are commonly used for smoking fish in Holland. The Danes use damp alderwood and partially smother the flames with oak or beech sawdust.

In some smoke-houses the fires are built in fire boxes or furnaces, in others the fires are simply kindled on the ground. In cold smoking, the fires must burn very slowly so that the fish are smoked at a comparatively low temperature. When the fires are built on the ground on the floor of the smoke-house, as is the case in the Maine herring smoke-houses, small logs from 4 to 8 inches in diameter are usually arranged in heaps a few feet from each other and about 4 feet from the side of the building. Two or three logs are placed together with a small quantity of kindling, and from 6 to 12 of these heaps are placed in each smoke-house. The limited supply of air in the house causes the logs to burn very slowly producing a large quantity of smoke; the fires are carefully watched and, if they burn too briskly, they are smothered with ashes.

Smoking Processes.

Small fish are usually smoked round (without cleaning other than washing and scaling). Larger fish, or smaller ones containing much feed, are always eviscerated. Large fish are always split and may be beheaded or cut into strips or small pieces with or without the skin removed.

In Europe and America, fish are always salted for a longer or shorter period, depending upon the product desired. This is accomplished either by immersion of the fish in brine or by adding dry salt to the fish. In the Orient, fish are often smoked without the preliminary salting.

The two main types of smoking processes are hot-smoking and cold-smoking. According to the latter process, the fish are hung some distance from the fire and are smoked at a temperature not exceeding 80° F. When the fish are smoked according to the hot-smoking process, the fish are kept close to the fire and are wholly or partly cooked while being smoked. The time required for cold-smoking varies from a few hours, as in the case of kippered products, to several weeks, as in curing hard herring; whereas the hot-smoking process is always completed within a few hours. Hot-smoking is generally employed in Germany and Sweden. Cold-smoking is chiefly used in the United States, Scotland, England, Norway, Holland and Russia, and is employed for the curing of herring, alewives, mackerel, halibut, haddock, salmon and other marine fish. Sturgeon and eels are largely hot-smoked.

Some fish-smokers use certain fungicides and antiseptics to prevent bacterial spoilage and molding during storage. Mixtures of boric acid, salicylic acid and salt are often sprinkled over smoked haddock to prevent spoilage.

Chemistry Involved in the Preservation of Fish by Smoking.

Very little work has been done to show the nature of the changes occurring in fish during smoking. The preliminary salting effects a removal of some water; some salt also passes into the fish. These changes inhibit bacterial growth to a certain extent and keep the fish in good condition while it is being smoked.

The efficiency of the preservation effected by cold-smoking depends to a large extent upon the drying out of the fish. The moisture content is reduced to such an extent that bacterial growth is practically inhibited.

In addition to the loss of moisture, smoking has a preservative action due to the wood creosote constituents which are found in the smoke and which are deposited in the fish. No one has determined the amounts of wood creosote in smoked fish but, doubtless, the amounts are very small. The wood creosote constituents as determined in the products of wood distillation consist of xylenols, guaiacol, creosol and other methyl ethers of higher phenols. There is possibly a very small amount of lower phenols such as cresol and phenol, but they are certainly present in very small quantities. The number of organic compounds occurring in wood smoke is very great and there may be other compounds deposited on the fish which also have a powerful preservative action. Different woods and smokes produced in various ways differ widely in their composition. A chemical problem of great importance is the discovery of the types of smoke producing the maximum antiseptic action.

In hot-smoking processes where the fish is partially cooked, the enzymes producing autolysis of the tissues are destroyed by the heat. The proteins coagulable by heat are coagulated, and thus the texture of the flesh is altered.

The Smoking of Herring.

Herring was one of the first marine products to be preserved on a commercial scale by smoking. The present industry is the most important smoked fish industry in the world; its chief centers are in Maine, Nova Scotia, England, Scotland, Holland, France and Norway. The Maine industry is centered in Eastport and Lubec, and produces about 13 million pounds of smoked herring annually. Scotland produces more smoked herring than any other country; of the 246,330,600 pounds of herring landed in 1921, 656,366 barrels were cured, and of these 184,530 barrels or about 53,698,230 pounds were smoked.

American Methods of Smoking Herring.

Smoking Processes.—There are three important methods of smoking herring by which three widely different products are obtained. Those herring which are thoroughly salted and smoked until they are hard and dry are termed red or hard herring. Two varieties of lightly smoked herring are prepared commercially in large quantities. Bloaters are lightly salted, smoked, round herring, which are intended for immediate consumption. In the United States only the large, lightly smoked herring are termed bloaters; but in Europe herring of almost any size may be bloaters. Kippered herring are prepared by splitting and eviscerating the fish, and then lightly salting and smoking them.

Hard or Red Herring.

In the early days of the American smoked herring industry, the scales were removed from the fish before they were taken from the boat. This

TABLE 44

Smoked Fish Industry of Maine in 1921

Products	*Pounds*	*Value*
Smoked alewives	42,333	$ 2,925
Finnan haddie *	471,205	67,105
Kippered herring	78,080	9,148
Smoked herring—		
Bloaters	208,050	18,090
Lengthwise	160,225	13,868
Medium scale	44,000	2,770
Boneless	1,005,201	101,780
Whole	615,650	43,997
Total	2,624,744	$259,683

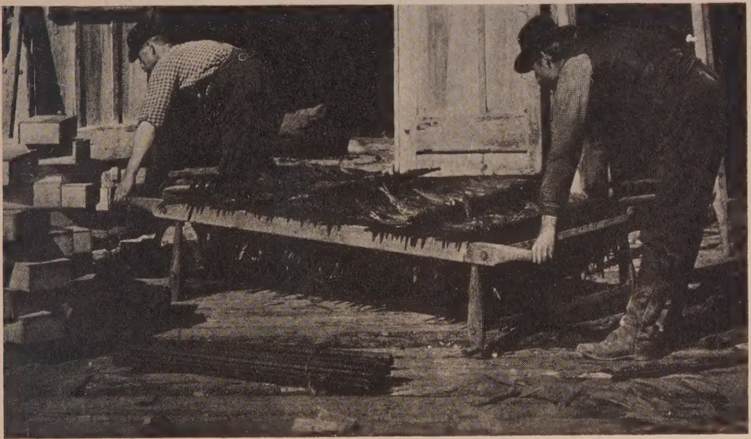
* Includes small quantity of finnan cod.

was accomplished by the fishermen who walked through the pile of fish without lifting their feet. This stirred the herring and thus removed most of the scales. The scaling was also accomplished in a somewhat different manner by stirring the fish with a spudger. Since about the year 1880, this scaling process has been discontinued to a large extent as it was found that the frequent handling of the fish removes nearly all of the scales before the fish reach the smoke-house. This not only saved much hard work, but lessened the number of bruised and broken-bellied herring.

The first step in the smoking process is pickling or salting. In America this is always effected by placing the fish in butts, tanks, or vats filled with strong brine; but in Europe the fish often are simply mixed with dry salt. If the herring are caught at sea at a distance from the home port of the fishing vessel, they are pickled on board the vessel soon after they are caught. When fresh herring intended for smoking are landed at the docks, they are taken to the salting sheds, and are immediately put into pickling vats partially filled with weak brine. Sufficient herring are placed in the vat to cover the bottom and then about a half bushel of salt is scattered over them. Another layer of fish, of from one to two barrels, is put in and a layer of salt, somewhat heavier than the first, being from 1 to 1½ bushels, is thrown over them. The tank is then filled with fish and covered with 3 to 5 bushels of salt. Each tank holds about 4 hogsheads of fish and the quantity of salt used varies from 6 to 9 bushels, depending upon the condition of the fish and the weather. The fresher the fish, and the cooler the weather, the less salt is required. The greater portion of the salt is placed on or near the top of the fish, so that in working down through the herring, it will dissolve before it reaches the bottom of the vat.

The small fish are allowed to remain in the brine from 24 to 36 hours, while the large ones are kept in the vat for about 48 hours, or until they are thoroughly "struck." The length of time which the fish remain in the vats depends to some extent upon the weather; the colder the weather the longer they are left in the brine.

When properly salted the herring are dipped out of the vats by means of dip nets or "wash nets." Usually as the fish are dipped out of the vats, they are washed in sea water or salt brine. After washing, or rinsing, they are laid on the stringing tables and allowed to drain. They are then strung on thin sticks about 3 feet 4 inches in length and ¾ inch square with one pointed end. The stringers raise the left gill cover of the herring and insert the pointed end of the stick through the gill slit and then through the mouth; at the same time the fish is shoved to the other end of the stick. Twenty-five to 35 herring are strung on each stick. A single person can string 500 to 1000 sticks a day.



Courtesy Bureau of Fisheries.

FIG. 129.—Herring on a herring horse.

The herring, which have been strung on the sticks, are washed by dipping them in a trough of sea water and hung on rectangular frames called "herring horses." Each "herring horse" holds about 45 sticks or 1 barrel of fish; and, when it has been filled, it is carried out into the open air where the fish are drained and slightly dried. This preliminary drying hardens the gill covers, thus preventing the fish from falling off the sticks in the smoke-house. The length of time which the herring are dried depends chiefly upon the weather. If it is foggy or rainy, the fish are drained for a few minutes, and are immediately placed in the smoke-house where they are dried. All the doors and windows are opened, and a hot fire is kept going in order to dry the fish quickly.

Inasmuch as the herring are obtained in relatively small quantities, since the business is usually conducted on a small scale, some time is required to fill a smoke-house. Even when the herring are obtained in large quantities the smoke-houses are filled by degrees, in order to insure the thorough drying of the fish during the smoking process. If the house were completely filled with fish at one time, the atmosphere would become entirely saturated with moisture, and if the temperature should happen to fall the condensing moisture might spoil them.

When the fish have been dried outdoors sufficiently, the "herring horses" on which the herring are hung are brought into the smoke-houses and hung on the stringers on scantlings, which are just far enough apart so that either end of the sticks, on which the herring are hung, rests on a scantling. The sticks are placed far enough apart so that the herring do not touch each other. The lower part of the "bays" in the smoke-house is usually filled first. When one day's supply of herring has been placed in the smoke-house, the smoking fires are kindled and the fish are smoked for 12 to 15 hours. The fires are then allowed to go down, and the partially smoked herring are shifted to a place nearer the top of the smoke-house. Another lot of fish is then placed in the lower part of the smoke-house and the preliminary smoking is repeated. Usually about two weeks' time is taken in the filling of the smoke-house, although this depends to some extent upon the size of the smoke-house.

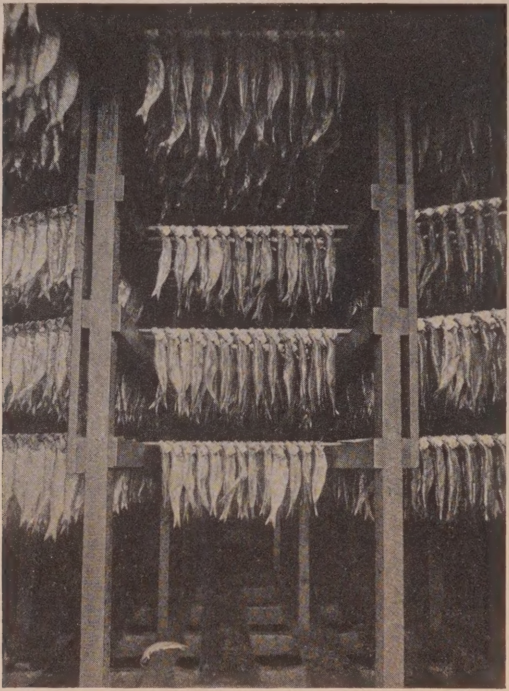


FIG. 130.—Smoked herring in smoke-house.

After the smoke-house has been filled and all of the herring have been given a preliminary smoking, the herring are given an additional smoking of about 3 weeks' duration.

Usually the fish are not taken from the smoke-house until they are to be packed or boned. If the packing is delayed some time after the smoking has been completed, the smoke-house is kept open during the day, and, during damp weather, fires are kindled to prevent the fish from becoming wet.

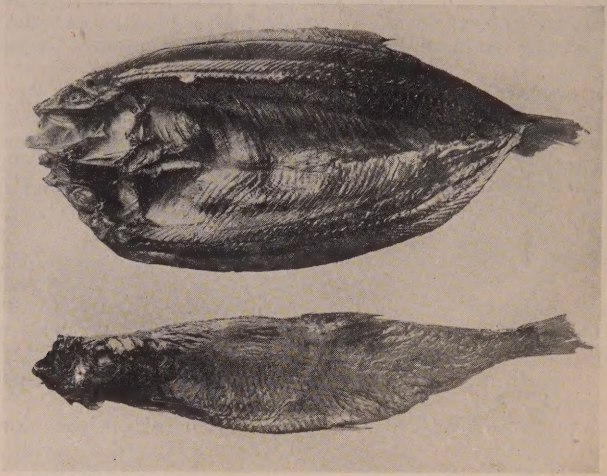
When the herring are to be packed, they are removed to the packing house where they are sorted into grades according to their size and fatness and packed in herring boxes. The principal grades of hard herring are "medium-scaled," "lengthwise" and "No. 1." The best grade is "medium-scaled," which is divided into two sizes known as large and small-medium. Medium-scaled herring are packed crosswise in wooden boxes; a box of the large medium-scaled herring contains from 30 to 40 fish, and the boxes of the medium size average 45 to the box. The "lengthwise" herring are larger than the medium-scaled and receive their name from being packed lengthwise of the box, which contains from 15 to 18 smoked fish. The "No. 1" herring are the smallest and least valuable of those regularly packed; each box contains from 60 to 75 fish. Other grades of smoked hard herring less generally recognized are "tuck-tails" and "Magdalens."

In the preparation of boneless smoked herring, the fish are dumped on wooden tables; the heads, bellies and tails are clipped off with scissors. The cut fish are taken to other tables where they are weighed. Women and girls then remove the skin and bones with their fingers; the faster workers can skin and bone 100 to 150 pounds of herring daily. The prepared herring are usually packed in wooden boxes lined with paper and are then ready for shipment. Some of the boneless fish is packed in small bottles, jars, and tins, in which form it is popular with certain classes of consumers. One hundred pounds of smoked fish yield about 30 pounds of boneless herring. This product and the canned kippered herring are the most valuable smoked herring products.

Bloaters.

In Maine only the large herring are used for the preparation of bloater herring. These are prepared in a manner much resembling that followed in the curing of hard smoked herring, except that the fish are salted for a somewhat longer period and are smoked lightly but at a higher temperature. In the preparation of bloaters from fresh herring, the fish are placed in strong brine for 2 to 3 days; then they are washed and strung on sticks. The herring are then drained and placed in the smoke-house on the lower bays where they are close to the fire. They are kept in the smoke-house for a period not exceeding 7 days and usually about 3 days. Since the bloaters are prepared only for immediate consumption and cannot be stored for long periods, the length of period of smoking depends to a large extent upon the distance of the market and the demands of the particular trade that is to be supplied. Bloaters are packed immediately after smoking, usually in boxes holding 100 fish each, containing about 35 pounds of fish.

Some bloaters are prepared from herring which are salted on board vessels, which when landed are very salty. In the preparation of bloaters from these salted herring, the fish are soaked in fresh water for some time to remove the surplus of salt which they contain. They are then strung on herring sticks and smoked in the same manner as fresh herring.



Courtesy of Fisheries.

FIG. 131.—Upper—kippered herring. Lower—bloater herring.

Kippered Herring.

Recently the kippering of herring has come to be one of the favorite ways of curing herring. Much kippered herring is canned, for this product is becoming a favorite among connoisseurs of smoked fish.

In kippering herring, the fish are split down the back from tail to head like mackerel as soon as they are landed and then placed in strong brine for about an hour. They are drained and slightly dried and hung in the smoke-house for 6 to 16 hours; and then packed for immediate shipment. Since this salting and smoking process is insufficient to keep the fish for more than a day or two at ordinary temperatures, kippered herring is a perishable product and cannot be kept for long periods or shipped great distances unless it is canned.

Foreign Processes of Smoking Herring.

The European herring fisheries are of far greater importance than the American herring fisheries; moreover a much larger proportion of the herring are smoked in the northern countries of Europe than in America. In Scotland in the year 1920 the herring catch was utilized as follows:

	1920	1921
Consumed fresh	70,028,800 lbs.	61,105,200 lbs.
Salted (gutted)	552,828 bbls.	457,552 bbls.
Salted (ungutted)	20,735 "	9,326 "
Kippered	253,483 "	174,494 "
Bloaters and "reds"	14,700 "	10,036 "
Canned	38,245 "	4,958 "

From these figures it is evident that a very large proportion of the herring which is cured by smoking in Scotland is kippered and a relatively small amount is cured as bloaters.

European red herring are cured in much the same manner as hard herring are prepared in the United States. The fish which are cured in this manner consist largely of those caught at sea and salted on board ship, and consequently are too heavily salted to be made into satisfactory kippers or bloaters. If they have been heavily salted on board ship, they are strung on sticks and soaked in fresh water to freshen them somewhat. They are then drained and dried slightly in the open. The length of the smoking process depends upon the trade for which they are intended; for local trade the smoking is continued for 10 days to 2 weeks, but for export trade the fish are smoked for three weeks or longer.

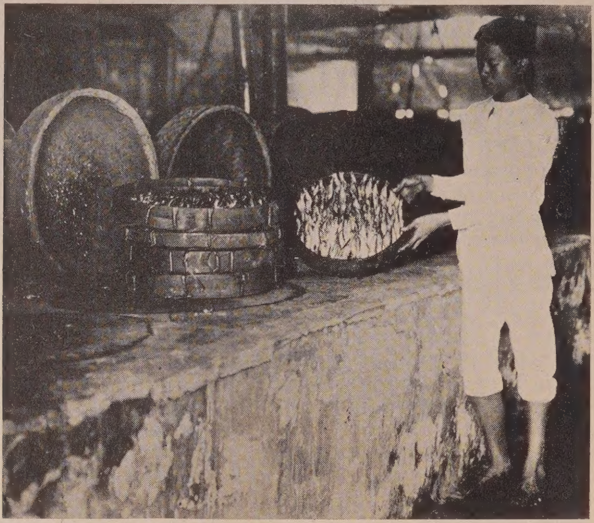
Bloater herring are prepared by the Europeans in a manner somewhat similar to that employed in America, but the herring are much more lightly salted and smoked. Much of the smoking of bloaters is carried out at the place of consumption. Lightly salted round herring are shipped to the large cities where they are lightly smoked and sold immediately.

The kippered herring industry of England and Scotland is the most important smoked fish industry. Herring intended for kippering must be very fresh and are split as soon as they are received. The salting is effected by immersing the split fish in strong brine from 15 to 60 minutes. After slightly drying the herring, they are hung on square sticks by means of hooks and smoked over a hot fire for 6 to 16 hours. Immediately after smoking they are packed in boxes and are ready for market.

In Holland, the greater part of the herring landed are caught in the North Sea, and are therefore heavily salted on board ship. They must therefore be freshened for about 24 hours before they are strung on willow branches for smoking.

In China and the Philippine Islands, herring are smoked in a peculiar oriental fashion. The round fish are dipped in salt water, washed and immersed in boiling water for a few minutes. The fish are then drained and spread in the sun for about an hour. About a hundred of the partially dried fish are put in a round basket. These baskets are placed over an opening in the top of a long stone or concrete furnace in which a smoky fire of hardwood sawdust is burning. Usually several baskets are placed one above another and over the top basket is placed a tightly woven cover. The smoking is continued for several hours, then the lowest basket is shifted to the top and the smoking is continued. The length of the smoking process depends chiefly upon the market for which the fish are intended. For the local markets, 24 hours' smoking is sufficient but for export trade or distant markets a longer period is required.

Many modifications of the processes of smoking herring that have been described are employed in various parts of the world, but space will not permit of a detailed description of these other methods.



Courtesy Philippine Bureau of Science.

FIG. 132.—Smoking small fish in Tondo, Manila, P. I.

The Smoking of Alewives or River Herring.

Relatively small quantities of river herring are smoked; some are smoked in New England but the principal industry is located in Virginia and Maryland. The process used in the Chesapeake region is similar to that employed in Maine in the smoking of the sea herring, except that the fish are lightly smoked. The washed, scaled river herring are put in strong brine over night. The following morning, they are strung on herring sticks, resembling those used in New England, and rinsed in fresh water. After draining and drying for a few hours, the strings of fish are hung in a smoke house, where they are smoked with a dense smoke for 2 to 3 days. Cured in this manner the fish will keep for about a month.

In Washington and Baltimore and a few other places, some alewives are gibbed, washed and salted in brine for a few hours. After drying slightly, these slightly salted river herring are smoked and steamed over a hot fire for about 3 hours.

The Smoking of Haddock.

Location of Industry.

The haddock smoking industry is second in importance only to the smoked herring business. In 1919, nearly 9 million pounds of haddock were cured in Maine by smoking; and in Scotland, over 77 per cent of the "white fish" (including cod, haddock, halibut, etc.) which were cured, were smoked. Nearly half of the "white fish" landed in Scotland were haddock. Table 45 gives the weights of haddock and cod which were smoked in Scotland during 1920 and 1921; 37,094,200 pounds of haddock were smoked by the Scotch fishermen in 1920. Much haddock is smoked in England, Norway, and Denmark, and some in Ireland.

The quantity of finnan haddie prepared in Maine where the industry is centered is given in Table 44.

TABLE 45

FISH SMOKED IN SCOTLAND

Description of Fish	1920	1921
Herring	70,041,253 lbs.	53,698,230 lbs.
Cod and codling	8,024,000	5,630,200
Ling	298,800	288,300
Saithe	3,550,500	1,136,900
Haddock	37,094,200	23,844,400
Whiting	4,442,700	2,253,500
Catfish	170,800	49,300
Mackerel	22,300	......
Total	123,644,553	86,900,830

The smoking of haddock originated about the middle of the eighteenth century at Findon, Scotland. This smoked haddock became very popular so the industry grew rapidly, and the curing of haddock by this method spread to other parts of Scotland and to England. The smoked haddock originally cured in Findon were called Findon haddocks, later this was abbreviated to Findon haddies and then to finnan haddies, by which name they are called to-day. In about 1850 the industry was introduced into the United States at Rockport, Massachusetts; but the smoking of haddock did not become an important industry until about 1875. By 1919 the industry had grown to such an extent that, in that year, over 13 million pounds of haddock were smoked in New England. Recently much smoked haddock has been canned and sold as "canned finnan haddie."

Scotch Method of Preparing Finnan Haddie.

The first step in the preparation of finnan haddie is the cleaning of the fresh fish which is accomplished by cutting off the head, splitting down the back, eviscerating and then giving an extra cut part of the way down the back behind the back bone from the right-hand side, in order to facilitate the curing of the thick muscles of the back. After washing, the fish is salted in strong brine for about half an hour. The slightly salted haddock are dried somewhat and spread open on sticks. The haddock are then hung in tiers in the smoke-house. The smoke is produced by slowly burning a mixture of peat and sawdust. The lowest row of haddock are hung about two feet above the fire; but the position of the haddock in the smoke-house is changed often during the smoking in order to obtain uniformly smoked fish. The smoking process lasts from five to six hours. Some curers wash the slightly smoked haddock in sea water to remove any soot deposited during the smoking.

The Scotch finnan haddies are marketed either in barrels or boxes containing about 150 pounds of fish.

Some haddock are heavily smoked in Scotland and sold as "smokies." These fish are beheaded, eviscerated but are not split; they are then lightly salted and smoked until they acquire a golden color.

American Method of Preparation of Finnan Haddie.

The American process of curing finnan haddies is similar to that described above; the fish are prepared for curing in the same manner but are salted and smoked for longer periods; moreover, peat is not used for fuel. The cleaned split fish are placed in strong salt brine for 1 to 2 hours; the exact degree of salting depends upon the size of the fish and the flavor desired. After "pickling" they are fastened to the sticks from which they are suspended in the smoke-houses, the napes being stretched out flat and pierced by two nails fixed in the smoke-sticks. These sticks are about 4 feet long and about 1½ inches square at the end. Three fish are usually hung from each stick. After being hung in the smoke-house, the haddock are allowed to dry for a few hours; then an oak fire is kindled and allowed to burn freely from 8 to 18 hours. The fire is then partially smothered

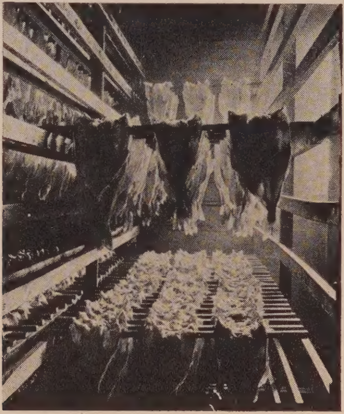


FIG. 133.—Smoking haddock in the preparation of finnan haddie.

in sawdust which produces a dense smoke. The smoking is continued for about 6 hours when the fires are extinguished and the fish are removed to the packing rooms where they are packed in boxes ready for market. Inasmuch as the smoking process has only partially cured the fish, they must be sold immediately. During warm weather finnan haddie will keep only a few days; but in the winter, it will keep for 2 or 3 weeks. The finnan haddie season lasts only from November until April.

The Smoking of Salmon.

Although much less salmon is smoked than herring and haddock, the product is one of the most valuable of smoked fish. In 1914, 4,248,896 pounds of salmon valued at $638,975 were smoked in the United States; and in the year 1919, 5,574,273 pounds of smoked salmon valued at $1,681,982 were produced. The values and amounts of salmon smoked in the United States where the industry is centered are given in Table 43 for the years 1914 and 1919.

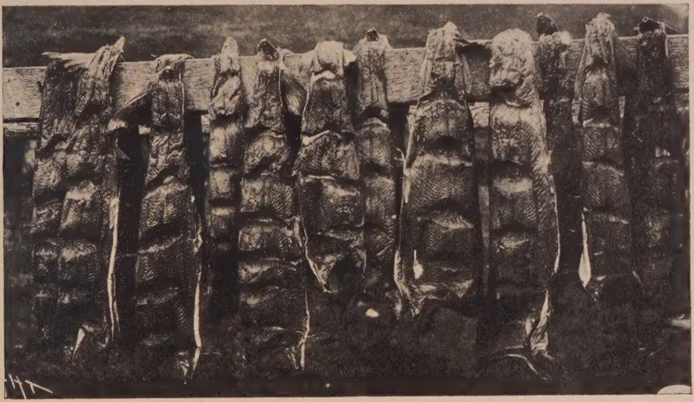


FIG. 134.—Alaskan, smoked, dried salmon.

Since the fishing season is relatively short, and the fishing grounds are in most cases far from the fish markets, salmon are usually preserved by salting soon after they are caught, and later shipped to the large cities. New York is the most important center of the salmon smoking industry. Mild-cured salted salmon are most used for the preparation of smoked salmon. However, when the fresh salmon market is glutted, much of the surplus of salmon is salted slightly and smoked.

The mild-cured salmon are removed from the barrels and soaked in tanks of fresh water for 2 to 12 hours, and then washed with a bristle brush until all slime and incrusted salt is washed off. If pickled salmon are used, they are freshened for a longer time. The cleaned, freshened fish are then drained and trimmed. Draining is often accomplished by "water-horsing," or piling in layers and weighting the piles to squeeze out the surplus water. The salmon are then spread out and laid flesh side down, and a wire bacon hanger, which has 6 or more points bent at right angles to the frame, is pressed firmly into the flesh on the skin side. The salmon are then hung upon a round stick and suspended in the smoke-house, and smoked by means of a fairly hot fire for 8 to 48 hours. Usually the smoking is continued with a low smoldering fire for 2 to 3 days. The length of the smoking period depends upon the length of time that the fish are kept before they are sold to the consumer, and upon the flavor demanded by the trade. Other factors which influence the time of smoking are the construction of the smoke-house and the temperature and the amount of smoke produced. When smoked to the desired degree the fish are removed to the packing house, wrapped in paper and packed in boxes.

In preparing frozen salmon for smoking, the fish are thawed by immersing them in water over night. The fish are then split down the belly, so that they will lie out flat, cleaned, and the head cut off. They are then salted by immersion in brine for a few hours.

Kippered Salmon.

Cobb[2] has described in some detail the preparation of kippered salmon as it is carried out on the Pacific Coast. His description is given below:

> On the Pacific coast practically all of the kippered salmon is prepared from frozen white-meated king salmon, which on account of the color of the flesh is not in much demand. It is, however, fully the equal, in both flavor and food value, of the red-meated kings. It is not absolutely essential that the fish be first frozen, as the fresh fish may be kippered after dressing, but the latter is always a little soft when so prepared, owing to an excess of moisture, which is largely removed in freezing. Fresh salmon is available only part of the year, so it is found most convenient to freeze and store the stock and work it up when needed throughout the year.
>
> Before freezing, the fish have been dressed, so when thawed in cold running water, it is only necessary to split and cut them into pieces of a pound or less, these being about 6 inches long, or perhaps 3 inches broad, depending upon the part of the fish the piece is taken from, and place them in a tank of strong brine to season for several hours. They are then dipped in a harmless vegetable coloring, similar to that used by the butchers for coloring sausage; this gives the outside of the product a red color, a concession to popular prejudice.
>
> From the coloring tank, the pieces are placed on a tray with wood frame and bottom of one-half inch square meshed wire; care is taken that the pieces do not touch each other.
>
> The tray is then slipped into a rack which will hold a number of these, placed one above the other, and this rack is then run on a track into the smokehouse.
>
> A medium fire is then kindled which dries and slightly smokes the pieces from 16 to 18 hours.
>
> When they reach a proper stage the fire is enlarged, but great care must be exercised in order to prevent their being overheated, and this is done by means of the damper at the bottom of the smoke-house and the ventilator at the top. The fish are baked in this manner from 25 to 35 minutes, the thermometer showing from 250° to 275° of heat.
>
> When the cooking is completed the cars are pulled out and the fish allowed to cool, after which each piece is wrapped in a square of parchment paper and packed in a box which holds 10 pounds.

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[2] *Bureau Fisheries Rept.*, 1921, Appendix 1.

The product is quite perishable, and if it can not be used at once, when of course it is at its best, must be placed in cold storage. The packer endeavors to turn out daily only the amount he can market that day.

Foreign Methods.

The methods followed in smoking season in Germany and Sweden resemble those formerly used in America for smoking Newfoundland and Labrador salmon. The salted fish are freshened in cold water for 48 to 60 hours, during which period the water is changed several times. The freshened salmon are washed and hung in the air for about 6 hours in order to dry them partially. Then the fish are laid on a table where they are spread out and braced with three sticks along the back in order to keep them spread out during their suspension in the smokehouse. During the smoking process, the fish are subjected to a gentle heat for the first two hours and then to a dense smoke for 24 to 36 hours, until they acquire a dark red color.

The Smoking of Halibut.

At one time the smoking of halibut was an important American industry, but recently the scarcity of the fish and the enhanced demand for it by the fresh and frozen fish trade has limited the quantity smoked to a marked degree. The industry reached its maximum importance in 1872 when about 3 million pounds of this product were prepared. The industry was formerly centered in Gloucester, Massachusetts. At present the entire amount smoked in New England does not exceed 300,000 pounds per year.

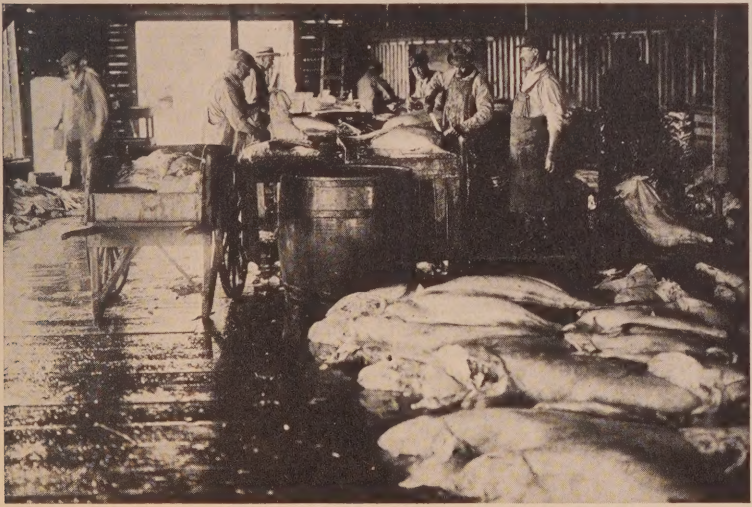

Fig. 135.—Butchering halibut for the preparation of smoked halibut.

Most of the halibut used for smoking is received from the banks in a salted condition; but some is received from the vessels supplying the fresh fish trade when the market is glutted. Some slightly soured halibut, which is considered unfit for sale as fresh halibut, is salted and smoked.

When the halibut is prepared for smoking, the thoroughly salted fletches, or halves of halibut, are removed from the kenches, washed thoroughly, and freshened in water for about 8 hours. They are then drained for a few hours by water-horsing, or compressing in regular piles; after which the halibut are spread on flakes similar to those on which salted cod are dried, where they remain two days during fair weather; but during damp weather a much longer period is required. At night and during rainy weather, the fish are collected in small piles and covered with flake boxes. When the fletches are dry, they are cut in small pieces, from 2 to 6 pieces to the fletch, depending upon the size. These pieces of freshened, dried halibut are then strung on hardwood sticks or small iron or steel rods which pass through the splits or gashes cut in the fletches. The sticks or rods holding the halibut are then placed on bars in the smoke-house. The smoke is usually produced by burning oak chips partly covered with sawdust. The fires are kept smoking until the halibut is considered cured which requires from 2 to 5 days. During cold weather, hot fires may be used for smoking the halibut and this operation can be accomplished in less time than in warmer weather. One hundred pounds of fresh halibut yield about 30 pounds of the smoked product. The smoked halibut is marketed in grades classified according to the thickness of the strips, viz.: "heavy chunks," "medium chunks," and strips. Little halibut is smoked in countries other than America and little is exported.

The Smoking of Mackerel.

A comparatively small amount of mackerel is cured by smoking. Mackerel is an expensive fish and is in great demand both as fresh and salted fish. About 25,000 pounds of mackerel are smoked annually in Scotland, and about the same amount in America; lesser amounts are smoked in England and other European countries.

In the United States, the fresh mackerel are cured without evisceration. The fish are salted in brine for about 12 hours; after salting they are opened at the vent to let the pickle in the abdominal cavity run out. Then the fish are hung on smoke-sticks, drained, dried and smoked for 4 to 5 hours. After this cold-smoking, the fires are increased and the fish are partially cooked by hot-smoking for a couple of hours.

Salted mackerel are freshened, dried and cold-smoked for 5 to 15 hours.

The Preparation of Smoked Eels.

There is little uniformity in the methods followed in smoking eels in this country. One method is to clean the eels by splitting, eviscerating, and beheading. The cleaned eels are salted in strong brine for about 24 hours, and are then thoroughly washed. The fish are strung on rods and hung in a smoke-house. The eels are hot-smoked over a hot fire of corn cobs and kindling until they are nearly cooked; then the fire is partially smothered with sawdust which produces a dense smoke that soon cures the eels. The total length of time that the eels are kept in the smoke-house is about four hours.

In many districts the eels are neither skinned nor beheaded, and are cold-smoked for about 4 hours before being cooked over a hotter fire.

In Germany it is a common practice to cover the eels with a paste made of sugar, saltpeter, anchovies, salt and butter before smoking in a cool smoke-house for 5 or 6 days.

The Smoking of Sturgeon and Other Fish.

Formerly, when fresh sturgeon was plentiful, large quantities of this fish were smoked; but as it became more and more scarce, the industry rapidly declined. In the year 1897 about 4 million pounds of sturgeon were smoked. The present industry probably does not produce one-tenth this amount.

The sturgeon are ordinarily cut into chunks about 3 inches wide weighing about 2 pounds. These chunks are usually salted in brine from 6 to 16 hours, although some sturgeon are dry-salted. The salted sturgeon is washed and strung on rods. The pieces of fish are placed in the smoke-house, and smoked over a low fire for 1 to 4 hours, then the fire is increased and the sturgeon is partially cooked from 1 to 2 hours. Many modifications of this process have been used, but since this industry is of such slight importance to-day, the details of these methods will not be considered.

Small quantities of shad, flounders, butterfish, and other marine fish are cured by smoking in the United States; but since these industries are so small, and because the methods used are similar to those already described, they will not be discussed.

Japanese Method of Smoking Bonito and Tuna.

In the curing of bonito (*Thynnus pelamys*), the fish is eviscerated, beheaded, boned and cut longitudinally into strips or wedges. These strips are either boiled or steamed and then placed in wooden trays with open-work bamboo bottoms and dried in the open air. When partially dried, the trays are placed on the smoking furnace. These furnaces are constructed of stone or concrete and have an open top above which a dozen or so of the trays containing the fish are piled so that the smoke passes up through the layers of fish in the trays. When the smoking process has been completed the strips of fish are a dark chocolate brown color and very hard. This product keeps very well and is a common article of diet of the Japanese. It is usually pared into shavings and forms the basis for sauces and broths.

Tuna (usually *Thynnus sibi*) and mackerel are prepared in a similar fashion by the Japanese.

Trepang.

Filipino Method.

The smoking of trepang is an important industry on some of the Philippine Islands. Seale[3] has described the smoking and drying of trepang on the islands of Mindanao and Sulu:

> Trepang are gathered at low tide. The fisherman usually walks along the reef, carrying a single-pronged spear with which he transfixes the animals. In deeper water it is necessary to dive for them. The best grades are usually in water from 3.5 to 6 meters deep or even deeper. In some places small dredges could be operated to advantage.
>
> After the trepang are gathered, they are taken to the curing station and cared for promptly; otherwise they become a blubbery, unsavory mess within a few hours. They are first placed in a pot or caldron of water (an oil tin would answer the same purpose) and boiled for twenty minutes (some require less time). When taken out of the boiling water, they should be hard and elastic and should dry quickly like a hard-boiled egg. They are slit open with a sharp-pointed knife, and the entrails are removed. They are next placed in the sun and left until almost dry and then transferred to a smoke-house, and smoked for about twenty-four hours. The smoked trepang are spread on a mat in the sun until perfectly dry. Finally they are packed in bags.

Chinese Method.

The method of smoking trepang used by the Chinese has been described by Cobb[4] in the following manner:

> In preparing it for the Chinese market, the animals are taken straight ashore, split open with a knife and the viscera taken out, and are then boiled in a deep iron try-pot. Previously a substantial drying shed has been built, walled in from the winds on every side, and only the narrowest of entrances left. Within should be constructed a platform of shutters of reed or other grass, raised some 4 or 5 feet above the floor. On these the holothurians, after the boiling process, are laid out to dry in a dense column of smoke which a carefully tended fire of driftwood sends up night and day. When thoroughly cured, in the course of which process they undergo considerable shrinkage, the animals, according to their class, are put into sacks, and are then ready for shipment. They must be kept dry at all times as they spoil very rapidly with the least damp.

Other Smoked Fish Products.

In Norway smoked fish is packed in a variety of unusual ways. Salmon is boiled or marinated in oil, then smoked and packed in oil; smoked sturgeon is packed in oil. Skinned and boneless smoked herring are put up both in oil and in jelly. Another unusual product prepared by Norwegian fishermen is smoked cod roe.

The Preservation of Fish by Drying.

The Location and Importance of the Industry.

Just as the aborigines of the temperate and frigid zones learned to preserve fish by drying and smoking over fires, so the wild tribes in the tropics found that their surplus of fish could be cured in the sun either with or without salting until the day when fish were not easily caught. In most tropical countries nature supplies an abundance of food that may be had for the gathering. Because of the torrid climate and the abundance of food the natives are not inventive and seldom take the trouble to improve either their mode of living or the preparation of their food. In the temperate and frigid zones, where fresh foods can be obtained only with great difficulty at certain seasons of the year, the people have been forced through necessity to study food preservation. Thus, although these zones are not adapted to the drying of fish, nearly all progress along this line has come in regions having cool climates. Although foods are most economically handled and transported in the dehydrated form, most foods are more palatable when preserved in other ways. This is especially true when fish are dried by the ordinary crude drying processes. Recently it has been discovered that if fish is quickly dehydrated according to the most up-to-date procedure, it can be preserved in a form that is superior in many respects to salted fish. During the World War, when the transportation system of this country was hard pressed, several comprehensive researches were carried out to discover methods of preparing dehydrated fish economically and satisfactorily from a culinary standpoint. These researches were eminently successful and at least two satisfactory processes have been proposed for use in this country. Germany has for many years been a leading nation in the preparation of dried products, and as early as 1913 scientific dehydration methods had been applied to the preservation of fish in that country. Since dehydrated fish weigh only about a tenth of the original weight of fresh fish, it is most economically stored and transported in this form; and this is where it possesses a great advantage over all other methods of preserving fish. There seems to be little doubt but that many new dehydrated fish products will appear on the market within the next few years.

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[3] *Philippine J. Sci., 12* (1917), Sec. D, 191-211.

[4] Increasing Our Pacific Coast Fishery Resources, *California War Papers, California State Council of Defense,* 1918.

Some fish is dried commercially in Europe, particularly in Germany; but the only countries where the drying of fish is an industry of the first magnitude are in the Orient. In India, China, the Philippine Islands and Japan, dried fish is one of the staple articles of diet of all classes of people. No detailed Indian or Chinese fishery statistics are available but in Japan the total value of all fish preserved by drying commercially in 1918 was $15,206,863. However, this figure includes the value of fish salted before drying and some smoked dried fish.

Principles of Dehydration.

If fresh fish is allowed to stand at ordinary temperatures, two decomposition processes immediately begin to break down the animal tissue of the fish. If these processes proceed far enough, the fish develops a foul odor and sour taste, and we say that the fish has spoiled. One of these processes is called autolysis, the other bacterial decomposition. Autolysis is brought about by the enzymes which during life effect many of the marvelous chemical reactions of metabolism and growth. These enzymes aid in the digestion of food and the restoration of worn out tissues of the body. Immediately after death these enzymes begin to tear down the complex proteins and fats of which the body is composed. Enzymes are easily destroyed by heat; bacteria may also be destroyed by heat but certain resistant forms of bacteria called spores are destroyed only when fish are heated to relatively high temperatures for rather long periods. If fish are boiled for a minute or two, the enzymes are destroyed and there is no longer danger of autolytic decomposition. To prevent bacterial decomposition, the fish may either be sterilized and stored under aseptic conditions such as in sealed tin or glass cans, or they may be kept under conditions unfavorable to bacterial growth. If certain conditions obtain, molds begin to grow on the fish and aid in the decomposition of the animal tissue.

Dehydration preserves fish by destroying enzymes and removing water necessary for bacterial and mold growth. Fat fish cannot be dehydrated by the ordinary dehydration processes, neither is it possible to store dehydrated fat fish in the usual way; for fish oils, or fats, are drying oils, which rapidly absorb oxygen from the air and harden just as paints harden upon exposure to air. Fatty fish must be dehydrated quickly in a vacuum, and must either be stored in vacuo or in an atmosphere of an inert gas. The dehydration processes considered in this chapter are applicable only to fish of low fat content (less than 0.2 per cent). No commercial attempts have been made to dry fatty fish.

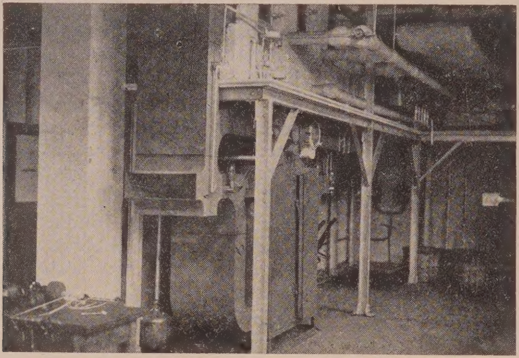


FIG. 136.—Experimental drier in Bureau of Fisheries' Fishery Products Laboratory, Washington, D. C. The temperature, humidity, and rate of movement of the air is automatically recorded

The preliminary boiling of meat or fish effects a complete destruction of the enzymes, a partial destruction of contaminating bacteria, and a partial dehydration. In addition to these three important changes, boiling effects many chemical reactions; the coagulable proteins are coagulated and some of the complex proteins are slightly hydrolyzed. Long continued boiling effects the complete hydrolysis of many of the proteins. However, it is rather doubtful if this preliminary boiling before dehydration is desirable; it is not necessary, for many of the modern dehydration processes for meat and fish are effected without it. The boiling removes some of the nutrients and also a portion of the flavor of the fish. Dehydrated products prepared without boiling retain all of the original nutrient substances, and more of the flavor than those dried after boiling. However, boiling effects a destruction of much of the cellular structure of the fish; this makes it easy to separate the bones and facilitates grinding or maceration preparatory to the drying process.

Dehydration of meat and fish is carried out commercially either by drying the substances in moving air currents or in vacuo. The old-fashioned drying of food-stuffs by spreading in the sun to dry may be placed in the first class of commercial processes. The rapidity of the removal of moisture in driers which dehydrate by passing warm air over fish depends upon the fineness of the division of the fish, the temperature, the humidity, and the rate of movement of the air. In general, the more rapidly the fish are dehydrated, the more rapidly the product can be rehydrated when it is needed for use. The reason for this has never been clearly demonstrated, but it is probably caused by the oxidation of the fat during the slow drying of the fish. An insoluble, hard, impervious film is slowly formed over the flakes of fish. This film being impervious retards the absorption of water by the dried fish. This theory appears more probable, when we consider that the longer dried fish is stored in air, the harder it becomes, and the less readily it is rehydrated. Evidently on standing in the air, whatever fat the fish contains gradually becomes oxidized to impervious linoxin, which impedes the rehydration process.

Although dehydrated fish absorbs a large quantity of water when it is soaked, it never approaches the water content of the fresh fish. This is evidently caused by the alteration of the physical structure and chemical nature of the fish during the drying process.

Storage of Dried Fish.

Although dehydration prevents autolytic changes, bacterial and mold growth, many chemical processes continue to act on dried fish. The most important of these, and the only process which proceeds so rapidly that the effects are easily noted, is oxidation. Oxidation proceeds most rapidly in sunlight in the presence of large volumes of warm air. Dehydrated fish should therefore always be compactly stored in opaque waterproof containers. Storage in vacuo or in an atmosphere of an inert gas is desirable although difficult to obtain. If the dehydrated fish is to be consumed within a relatively short time, friction top tin cans or even paraffined cardboard containers may be used. The more nearly optimum the conditions of storage the longer the dried fish may be stored without becoming a hard unpalatable material which will not rehydrate beyond a tough, rubber-like condition.

Oriental Methods.

Fish Drying in Bengal.

The uncivilized Orientals have dried fish in very crude ways for thousands of years. The methods in use to-day by the Chinese and Indians are evidently those used by their ancestors before the Christian Era.

These simple processes are of little importance save for their historical interest. Yet, many thousands of tons of fish which form the chief means of sustenance for millions of poor Chinese and Indians are preserved by drying in a very simple, unscientific manner. Southwell[5] has vividly described the manner in which fish are dried in Bengal, Bihar, and Orissa:

> The common variety of cured fish is known as *Sutki* or *Sukti*. . . . With the advent of winter, large fishing parties . . . proceed to the centers of capture and commence the preliminary arrangements for fishing. The drying operations begin in December, and continue till March or April, when the fishermen return home laden with boatloads of dried fish. The drying yard is called a *khola*. The process of drying fish is simple enough. The heads of the larger fishes are severed with a thin sharp bent *dao* (knife), the breasts cut open and the entrails pulled out by the fingers. Very large fishes are divided into pieces of suitable size. The smaller varieties are dried with the heads on, and the entrails are only squeezed out by the thumb. In Farid-pur, the entrails are trodden out when the fish is half dry. The smallest fish are dried entire. In Jalpaiguri, only, the fish are washed after cleaning. The cleaned fish are laid flat side by side on mats made of nal-reeds and exposed to the sun. In some localities they are laid in rows on bamboo platforms three or four feet high, or strung on a rope hung from two poles. In some parts of Assam they are dried on the hot sands on the bank of the Brahmaputra. A net hung on a bamboo frame is spread above the drying fish to protect them from the depredations of birds and other animals. At night the mats containing the dried fish are exposed in the air. This process continues day after day for a week or so. A week of fair weather is sufficient for drying fish, but if wet weather intervenes, the process is continued for a few days longer, and the quality of the dried fish deteriorates. In Jalpaiguri, fish is sometimes dried by a fire being lighted below the platform on which the fish are placed. A certain portion of the dried fish is sold on the *khola* (drying yard), but the bulk of it is brought home. Dried fish is sometimes preserved by being packed into large earthen jars called *mat-kas,* well smeared with fish oil inside and buried in shallow trenches in a shady place. But the greater portion of dried fish is kept in trenches dug in the ground. These trenches are about 2 feet deep and lined with mat and then with straw, over which the fish are placed and covered again with straw, and then with mats, and then with earth which is pressed down in the form of an arch and smoothed over. They are dug out from time to time as required. By this burial, dried fish acquires its peculiar brownish-red color, and the odor undergoes a certain change which is liked by the consumers. Smaller quantities are packed in gunny-bags. Fish dried in this way is supposed to keep good for one year but at all times it emits an offensive odor, but is palatable to the people who have acquired the taste for it. *Sutki* is made of only such varieties of fish which do not decompose easily and have firm flesh.

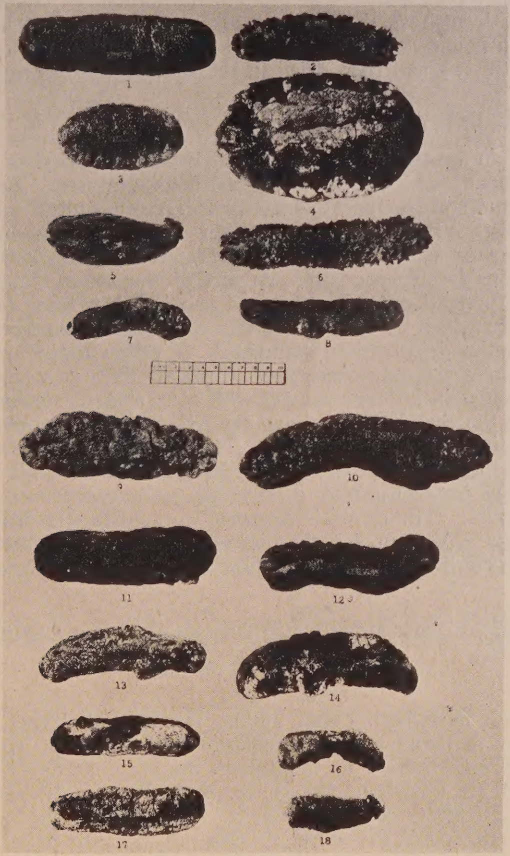
Japanese Dried Fish Products.

The dried fish industry of Japan is one of the most important fishery industries of that country. Large quantities of herring are dried annually in the preparation of "mikagi-nishin." This product is made by cutting off the heads and bellies of the herring, and then drying the cleaned fish on long bamboo tables or frames for about 10 days. The completely dried herring are tied into bundles containing 100 fish; 24 of these bundles of herring are packed into one "coil" in which package the fish are marketed.

Cod are dried in the preparation of a product known as "stick cod," which is made in a manner similar to that used in the preparation of the European stockfish. The fish are beheaded, eviscerated and cleaned; then the fish are dried in the sun until they become as stiff as sticks, hence the name.

[5] *Dept. of Fisheries, Bengal, Bihar, and Orissa,* Bull. 5, 1915.

The Japanese also salt mackerel, sardines, cod and other fish slightly and dry them in the sun in the preparation of "salt-dried" fish.



Courtesy Philippine Bureau of Science.

Fig. 137.—Philippine trepang or balatan, commonly dried and smoked.

Drying of Fish in the Hawaiian Islands.

Most of the fish caught in Hawaiian waters are sold fresh; those which are preserved are cured by simple drying processes. The smaller fish such as the *nehu* and *piha* are laid in round condition on coarse cloth, which is spread on the ground in the sun, until they are dried. The larger fish such as *opelu,* mullet, *akule* and *aku,* are split open and eviscerated. After cleaning, the fish are sprinkled with salt and put in a container over night. The following morning the salt is washed off in fresh water, after which they are placed upon racks or boards, covered with cocoanut leaves and left in the sun until they are completely dried. Very large fish such as the albacore are cut into square chunks, which weigh about a pound each, and scored; after which the chunks are rubbed and kneaded in salt and then dried in the sun.

The Modern Dehydration Process.

Recently an up-to-date process of dehydrating fish has been introduced in Germany which includes several novel features. The first plant of its kind was constructed at Oxstedt, Cuxhaven, and is operated on a scientific basis. After the fish have been cleaned and washed, they are placed in presses which are about 5 feet in diameter and capable of developing considerable pressure. A part of the water that is contained in the fish is pressed out. The pressed fish are then hung on lath racks built on trucks which run on small rails. The trucks containing the fish are run into the dehydration chambers. A powerful motor operates a fan which forces a strong current of warm air through a tower-chamber in which it comes in intimate contact with concentrated sulphuric acid and then through the chamber containing the fish. As the dry air passes into the chamber, it is mixed with ozone. The air is heated by means of gas burners. The fish are kept in the dehydration chamber until they become quite dry. The product is said to possess a good appearance and excellent keeping qualities. The ozone is supposed to sterilize the fish during the drying process. A plant for the concentration of the diluted sulphuric acid is run in conjunction with the dehydration factory.

Principles of Modern Dehydration Applied to the Drying of Fish.*

By George G. Scott †

Fish which have been cured by the salting and drying process are unsatisfactory in many ways. Much salt cod and other salt fish spoils before it is eaten. Usually these products are not guaranteed for a period longer than three months. The consumer must soak the salt fish for a relatively long time to remove the salt. Many persons do not relish the taste of salt fish, for, in the salting process, much of the flavor is removed.

The ancient processes of drying fish are still more unsatisfactory. As a rule they produce a dry, hard, nearly tasteless substance which is rehydrated with difficulty and is not appetizing when cooked.

Modern dehydration processes have been very successful in improving the quality of dried fruits and vegetables. The application of scientific methods to the drying of fish has been equally successful in preparing an excellent product. Properly preserved dehydrated fish possesses many advantages over dried salted fish. The long soaking to remove the salt is not necessary; fifteen to thirty minutes soaking in cold water will rehydrate the fish. It can be cooked in a few minutes and can be served in many appetizing dishes.

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* The methods presented in this section were proposed after extended researches by the writer as a Special Assistant in the Bureau of Fisheries. The processes were given thorough trials on a semi-commercial scale, but as yet they have not been adopted by any commercial concern.

† Professor of Physiology, College of the City of New York.

The Dehydration Process.[6]

Exhaustive researches were conducted relative to the application of modern dehydration processes to the preparation of dried fish. The results of this work are embodied in the process outlined below.

The fish are cleaned in the customary manner. The viscera, heads, fins and scales are removed. The fish are skinned either during the cleaning process or immediately after cooking. In most cases the skin is more easily removed after the cooking process.

The cleaned fish may be placed in shallow pans and cooked in a retort with live steam. When so prepared, the fish are kept in the retort under twelve pounds steam pressure for twenty minutes. The cooking may be effected equally well by placing the fish in boiling water for five minutes. Cooking kills the bacteria, destroys enzymes that would later bring about autolytic decomposition of the fish flesh, and softens the flesh so that it may be easily picked from the bones. This changes the flesh so that it may be easily ground preparatory to dehydration. Further, the cooking effects a partial dehydration of the fish; as about thirty per cent of the water is removed. There is no appreciable loss of food value during the cooking of fish.

The flesh is picked from the bones of the cooked fish; this operation is called flaking. One person can flake about a hundred pounds of cooked fish per hour.

After flaking, the fish is ground by a meat chopper or sausage grinder. The grinding plate used should have perforations of about three-sixteenths of an inch in diameter. Thus the fish is made into uniform cylindrelles for drying.

The ground fish is spread thinly on shallow drying trays, which are placed in a drier. Two types of driers are in common use. Vacuum driers are more efficient but their initial cost is high, and some time is required to open and close them as the vacuum must be released and made up again. Most of the experimental work on dehydration of fish has been done with driers which remove the moisture by means of warm, moving air. Fish, prepared as directed above, may be effectively and cheaply dehydrated in about two hours in a good warm air drier. The temperature of the drier should be about 145° F. at the start, and as the run continues, the temperature should be gradually reduced. Too high a temperature causes a marked darkening of the product. The temperature of the fish should not reach that of the air blowing over it. The drying should be discontinued when the moisture content is reduced to 5 per cent.

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[6] The process described is applicable only to fish containing little fat, such as cod, haddock, whiting, etc. Further researches will have to be carried out to permit the dehydration of fat fish; for the oil gradually turns brown and rancid when dried fat fish are stored.

The dried product is then coarsely ground, and removed to a dry packing room. The fish must be packed in air-tight containers; tin cans are the most satisfactory, but their cost is relatively high. Paraffined cartons may be used, provided the fish is not stored for a long period.

Character of the Product.

The product of this dehydration process is a highly nutritious food containing about 80 per cent of protein. It is a concentrated, body-building food; for a hundred pounds of fresh fish yield only about nine pounds of dehydrated fish. This must be taken into account by both the producer and the buyer. The storage and shipping costs are reduced to a minimum.

The dehydrated fish can be ground into a meat flour which finds many uses. The manufacturer can mix dehydrated fish with dried vegetables and so make a dehydrated fish chowder. Similarly, dehydrated fish cakes may be put on the market. Fish meal when mixed with flour produces a macaroni that is much richer than the present known macaroni. In fact, the protein and carbohydrate may be mixed scientifically so that the product will have the requisite amount of protein and carbohydrate needed for a proper diet.

To use this dehydrated fish, all that is necessary is to add about three times its weight of water and allow it to soak for fifteen to thirty minutes, then it is boiled for a few minutes and the dish is ready to be served.

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Chapter 19.

Canning of Fish and Fish Products.

By H. M. LOOMIS *

The canning of fish in the United States dates from about 1820 when Thomas Kensett and his partner, Ezra Daggett, started the canning of lobsters and other sea food in New York City. On account of the lack of any scientific basis for the industry, its development was slow, as the process was expensive and the losses in some cases very heavy. The canning of oysters and other sea foods began in Baltimore about 1835, and the experimental canning of sardines was begun at Eastport, Maine, about 1840. Upon the Pacific Coast, fish canning started with the opening of a salmon cannery on the Sacramento River about 1860, the canning of salmon rapidly spreading northward until it now extends from its original starting point to the Yukon River, Alaska. The canning of sardines and tuna in southern California began a short time before the opening of the present century.

Canning is a comparatively modern method of preserving food, its origin dating from the discoveries of the French inventor, Nicholas Appert, in 1795. It has advantages over some of the more ancient and well-known methods for food preservation such as drying, salting, cold storage, and freezing. Canning preserves to a large extent the natural flavor of the original food, and at the same time the product is put up in such form that it can be readily transported and kept in any climate without appreciable deterioration. In fact, canned foods correspond closely to and have all the advantages of the fresh foods, prepared and cooked in the home.

The canning of the following varieties of fish and fish products has reached commercial importance in this country: Salmon, sardines, shad, tuna, herring, mackerel, cod, haddock and roe. At present the salmon canning industry is the most important fishery industry in America. It is located on the Pacific Coast from Monterey Bay in California to the Yukon River, Alaska. Sardines are canned along the entire coast of Maine and in California from Monterey to San Diego. The American tuna industry is also situated in southern California from Monterey to San Diego.

Sardines, mackerel, herring, anchovies, roe, and tuna are canned in various ways in several European countries, while salmon and swordfish are canned in Japan and along the coast of Asia. Canada contributes very largely to the production of canned salmon.

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* Assistant Secretary, National Canners Association.

Outline of Canning Methods.

The important steps in the canning of fish and the purpose of each are briefly described below. The procedure necessarily varies considerably with different fish and with different products of the same fish. A more detailed description of the methods employed is given under the particular products covered in this chapter.

Heat and Power.—In planning a fish cannery it is most important that liberal provision be made for power. Canners require a supply of steam for heating or cooking purposes, as well as for cleaning, in addition to whatever may be used for power. The boiler capacity should be much more than sufficient to take care of the plant when running at full capacity, and it is also desirable to have some reserve in case of a breakdown. A boiler that is constantly required to give service up to the limit of or beyond its capacity is in danger of breaking down and the steam supply is apt to be wet.

Though steam power is used in most canneries for operating machinery, there is a continual increase in the number of machines operating with individual electric motors. The question of which method of operation is more economical depends largely on local conditions.

Cans.—The two styles of tin cans used in canning of fish are the hole and cap cans and the open-top or "sanitary" can, though the former is practically obsolete in the United States. "In[1] the latter, the entire end of the can is applied after the filling is done and the can is closed by crimping or double-seaming the end to the body, no acid or solder being used. Instead of solder, a form of cement or rubber gasket is used to assist in making a tight enclosure."

"The containers are also classed as plain and enamel-lined, the latter type being used for some fish products of an acid character, such as sardines in mustard or tomato sauce. A few products, as shrimp, crab meat, some tuna, and fish flakes, are packed in paper-lined cans for the purpose of preventing any dark spots through contact of the contents with the metal. Wood and other liners have been used, but paper has nearly superseded all others. Outside lacquering is generally done upon goods to be exported, or upon those likely to be exposed to dampness or salt air, to prevent rusting. A great variety of sizes of cans are in use, so that the consumer may get a product in almost any convenient quantity."

Cleaning and Trimming.—In the canning of fish products, cleaning and trimming generally consist in the removal of the head, viscera and tail fin, the washing of the eviscerated fish to remove blood, etc., and the trimming of the fish into pieces of proper size to pack into cans. Although in many branches of the industry this work is done by hand, mechanical contrivances have been worked out to a greater or less extent in connection with the canning of sardines, and have reached a very high degree of perfection in the case of the salmon canning industry, as will be described later.

Brining or Pickling.—In order to draw out the blood from the tissues of the fish, to give the flesh a proper degree of firmness and the desired

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[1] "Canned Foods," *U. S. Dept. Commerce,* Misc. Bull. *54* (1917), 25.

TABLE 46

SIZES, DIMENSIONS, AND WEIGHT OF CONTENTS OF CANS PRINCIPALLY USED IN THE UNITED STATES

Designation	Dimensions	Approximate Net Weight
Salmon—		
No. 1. Tall	3 1/16 x 4 11/16	1 lb.
No. 1. Flat	4 1/16 x 2 21/32	1 lb.
No. ½	3 7/16 x 2 1/32	8 oz.
California Sardines—		
¼ key	4 5/16 x 3 3/32 x ⅞	3¼ oz.
½ oval	5 15/16 x 3⅜ x 1 3/16	7 oz.
1 oval	6⅝ x 4½ x 1½	15 oz.
Maine Sardines—		
¼ keyless	4 5/16 x 3 3/32 x 29/32	3¼ oz.
¼ 3-piece key	4 5/16 x 3 3/32 x ⅞	3¼ oz.
¾ keyless	4¾ x 3½ x 1¾	10 oz.
¾ key	4⅝ x 3 15/32 x 1 23/32	10 oz.
Kippered Herring—		
½ oval	5 5/16 x 3 9/16 x 1 3/16	7 oz.
1 oval	6⅝ x 4½ x 1½	15 oz.
Tuna—		
¼ round	2 11/16 x 1¾	3½ oz.
½ round	3⅜ x 1 13/16	7 oz.
1 round	4 x 2⅜	15 oz.

flavor, it is the practice to hold many kinds of fish before or after trimming in a strong brine for a varied length of time. The time of holding and the strength of the brine used depend largely upon the size and fatness of the fish and the nature of the subsequent canning operations.

Cooking.—Many fish are subjected to some cooking or drying process before being packed into cans, salmon being the most notable exception. This removes excess moisture and supplements the cooking of the fish in the can during the subsequent sterilizing process. In the case of sardines one of two methods are usually followed: the fish are either steamed and dried before packing, or they are dried first and then cooked by a frying process.

Packing.—The nature of most fish products makes it practically impossible to pack them mechanically with the exception of salmon. Therefore nearly all fish products are packed by hand.

Exhausting.—In order to insure a proper vacuum in cans before sealing and to shorten the time required for the sterilizing process, it is common in many fish canning operations to exhaust the cans before they are sealed, that is, to pass them on an endless belt through a steam chamber for a period varying usually from 5 to 15 minutes, and at an approximate temperature of 212 degrees F.

Sealing.—The old-time method of sealing cans by means of solder has been almost entirely displaced by the more modern method of rolled seams; and machines for closing cans in this way have reached a high degree of perfection, the cans being sealed at the rate of 100 to 125 per minute.

Processing.—The canning of food products being based on the principle of sterilizing by heat, the final cooking or "process" as it is called, is the most vital and important step in the canning procedure.

On account of the solidity with which fish products are ordinarily packed in cans, the heat penetration is necessarily slow and in order to secure adequate sterilization within a reasonable time it is customary to sterilize such products in retorts under pressure. A temperature varying from 230 to 240 degrees F. is ordinarily used.

Testing.—After the cans have been cooled, it is customary to test them for leaks or defective seams before they are finally packed in cases for shipment.

The Salmon Canning Industry.*

Value and Importance.

The value and importance of the salmon canning industry will be realized from a study of the following brief table summarizing the number of cases of salmon packed since the inception of salmon canning on the Pacific Coast in 1864. This table gives the total cases packed for the whole North American Coast, including British Columbia, and, for the sake of brevity, is given in ten-year periods, with the exception of the first period which covers only eight years.

Period	Cases (48 pounds per case)
1864–1871	504,000
1872–1881	5,013,861
1882–1891	11,709,915
1892–1901	26,864,515
1902–1911	43,244,258
1912–1921	73,377,223
Total, 1864–1921	160,713,772
Pack of 1922	6,443,349

Recent years have witnessed the introduction and gradual growth of the industry on the coasts of Siberia and Northern Japan, and the annual pack from these sources now amounts to approximately 750,000 cases.

In addition to the salmon which are canned, millions are preserved each year in various other ways, such as drying, salting, and freezing. However, more are canned than are preserved in all other ways combined. The total annual pack of canned salmon averages about 7,000,000 cases and represents a value to the canners of some $55,000,000.

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* The following sections relating to salmon were prepared by Dr. E. D. Clark, Director of Fisheries Investigations, National Canners Association, and his associates, Drs. R. W. Clough and C. R. Fellers, to whom grateful acknowledgment is due. H. M. L.

Catching the Salmon.

The salmon industry depends to a great extent upon the spawning migration, for it is only at this time that the salmon may be caught in quantity, and indeed three of the species are almost never caught at any other time. Coming in from the open sea in immense schools, they fall an easy prey to various types of nets, to traps, and even to hook and line. In general, salmon are taken either by "fixed gear" or by "floating gear." The "fixed gear" includes traps, consisting of large stationary pound nets constructed of piling, wire netting, and linen netting; and fish wheels operated by the river current, which as they revolve pick up the salmon and throw them into a box by the side of the wheels. The "floating gear" includes purse seine boats, gill net boats, trolling (hook and line) boats, and floating traps. Sometimes beach seines, dip nets, and spears, are also used.

Transportation of the Salmon.

The salmon caught in traps are "brailed" out or scooped into scows or cannery tenders. Those caught by hook or by nets are sometimes taken to the cannery in the fishing boats, but more frequently they are transferred to larger boats known as tenders, which make regular trips to the places where the fishermen are operating. On arrival at the cannery the fish are either pitched with one-tined forks called "pews," or are sluiced with a stream of water into an elevator which takes them to the cannery floor. The sluicing method is preferable to the use of "pews."

The Canning Process.

The industry is carried on to a large extent in the unsettled and almost inaccessible districts of Alaska. Most of the supplies, machinery, food, labor, and, in short, everything but the fish are brought from the United States. To handle large quantities of fish during the short period when the salmon are running is possible only by eliminating nearly all handwork and using high speed automatic machinery and conveyors. Indian, Oriental or other foreign labor is sufficiently skilled for most of the cannery work, but white men must be employed as machinists, engineers, cookers, can makers, and for other positions requiring judgment and special training.

The ideal cannery location will include:

1. A plentiful supply of pure, fresh water.
2. Sufficient level ground on which to erect the necessary buildings in healthful surroundings.
3. Sufficient depth of water at the dock to permit the landing of boats at all tides.
4. Nearness to the fishing grounds, which will obviate the necessity of long hauls with the consequent danger of spoilage in transit to the cannery.
5. Provision for adequate removal of waste and sewage.

Nothing is added in canning salmon except salt; therefore the strictly manufacturing phases are reduced to a minimum compared with the canning of other fish products like sardines, tuna, kippered herring, and so on.

When canning begins the fish are fed, either by a conveyor or pewed by hand, to a table near the fish dressing and cleaning machine known as the "iron chink." The "iron chink" is a complicated machine, which by a series of knives and brushes rapidly removes the heads, fins, tails and entrails of the fish under jets of running water. The next stage is the "sliming" of the salmon, which may be done either by machine or by hand. This consists in removing any of the blood, slime, loose membranes, etc., which were not removed by the iron chink. After sliming, the dressed fish are fed into a cutting machine, where rapidly revolving knives cut them into slices of the proper size to fill one pound or one-half pound cans.

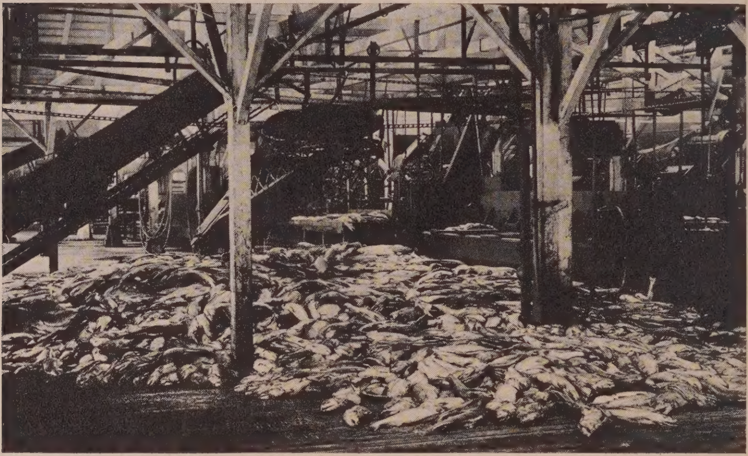

FIG. 138.—Salmon unloaded on cannery floor.

The empty cans are usually stored on the second story of a cannery and are fed down a chute into the automatic filling machine, which fills each can with the proper amount of fish and adds the desired amount of salt. A recent type of filling machine cuts the fish into slices, salts the cans, and fills them at the rate of 115 to 125 per minute. Many of the flat cans are filled by hand; this is particularly true of the chinook and sockeye salmon. The filled cans then pass on belts down to the "patching table," where they are either weighed automatically, or else inspected to see that they contain the proper amount of fish and have no bones or skin showing on the top of the cans. From the "patching table" they pass on moving belts to the "clincher" machine, where the tops are loosely

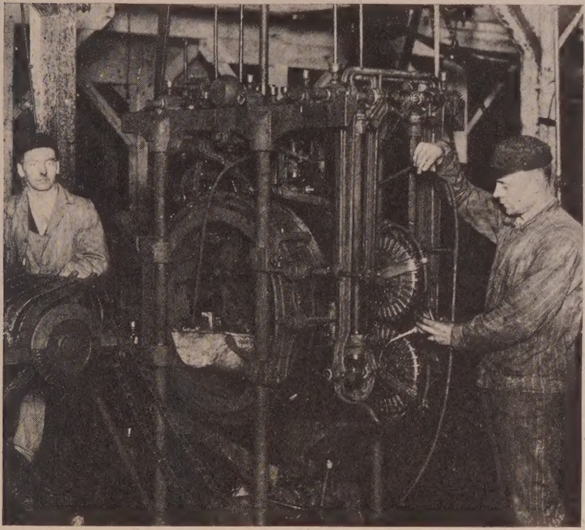

FIG. 139.—An "iron chink," a machine for butchering salmon.

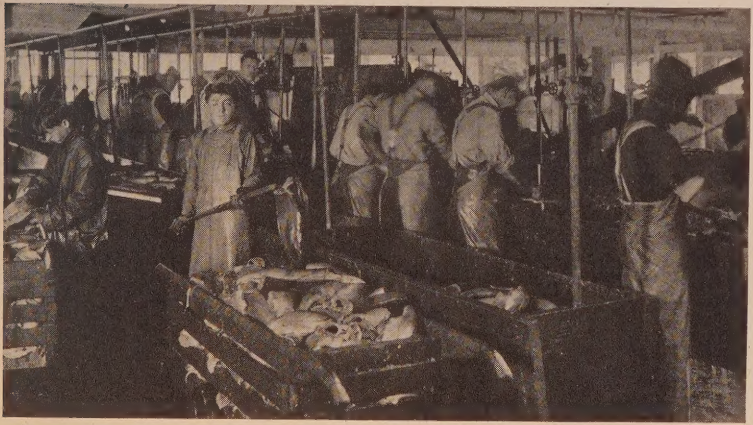

FIG. 140.—Trimming and washing salmon after passing through "iron chink."

crimped on the cans to prevent particles of fish from getting out of the cans and condensation water from getting into the cans during their passage, through live steam in the "exhaust box." The function of the exhaust is primarily to heat the filled cans sufficiently to drive out some of the air, thus ensuring sufficient vacuum in the can after cooling to keep the ends concave under all conditions of temperature and altitude. Usually cans are exhausted for 6 to 16 minutes in an exhaust box with live steam having a temperature of 200 to 210° F. The hot cans from the exhaust box pass immediately to the "closing machine" or "double seamer," which rolls the tops on very firmly, making the can air-tight. The cans then roll into "coolers" or large shallow trays made of flat, iron strips, which hold several dozen cans. Several of these "coolers" filled with cans are placed in a stack on a small car which rolls on tracks into the retorts for "processing" or cooking by steam under pressure.

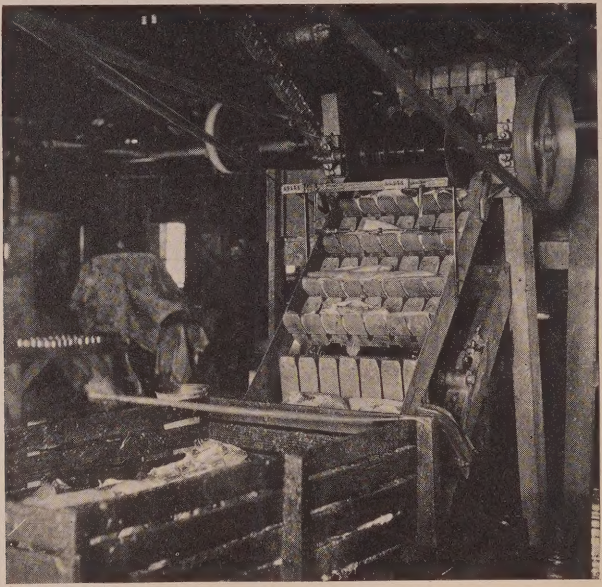

Fig. 141.—Machine for slicing salmon.

One pound cans of salmon are usually cooked from 80 to 90 minutes at 240 to 245° F. The one-half pound cans receive a process of about 70 to 75 minutes at the same temperature. After processing, the cars are rolled out of the retorts, and the coolers, filled with hot cans, are then passed through the "lye wash" to remove oil, washed with clean water and finally set aside on the floor of a warehouse over night to cool. As the interior of the cans are at a high temperature and pressure, any leaks which are present will show themselves in the "lye wash" by bubbles of air. Most of the defective cans are removed in this way; however, they are tested further, after being washed with hot water, by tapping on the distended ends with a short metal rod. Any can which has a dull sound is discarded, as it is an indication that it is leaking, otherwise it would ring on account of the considerable pressure that exists within.

Of course, there are some minor variations in methods of canning salmon, such as running the open cans through the "exhaust box," thus dispensing with the "clincher" machine; also, sealing the cans under a vacuum produced by vacuum pumps, thus eliminating the "exhaust box." As is already seen, the cans pass from the filling machine into the "coolers" practically automatically by means of belts and conveyors; for this reason it is obvious that each piece of machinery, including fillers, clinchers, exhaust box, and closing machine, must all be carefully timed and work in perfect synchronism.

After the retorted cans are cooled, they are sometimes lacquered in an automatic machine. However, there is an increasing tendency to do away with lacquering and to depend on enameled ends and labels to prevent rusting of the cans. The cans are usually labeled by automatic machinery which operates very rapidly. The three common sizes of salmon cans are the one pound tall, one pound flat, and one-half pound flat. A small amount of salmon is put up on the Columbia River in one pound oval and one-half pound oval cans. Salmon is usually marketed in cases containing 48 one pound, or 48 one-half pound cans; sometimes 96 one-half pound cans are put in larger cases.

The scientific and local names for the five species of Pacific salmon are given below:

Scientific Name	Puget Sound	Columbia River	Alaska	Other Names
1. *Oncorhynchus nerka*	Sockeye	Blueback	Alaska Red, Sockeye	Quinault, Redfish
2. *Oncorhynchus tschawytscha*	Spring	Chinook	King, Chinook	Tyee, Quinnat
3. *Oncorhynchus kisutch*	Coho, Silver	Silver	Medium Red, Coho	Silversides
4. *Oncorhynchus gorbuscha*	Pink	Pink	Pink	Humpback
5. *Oncorhynchus keta*	Chum	Chum	Chum	Keta, Dog, Calico

The Canned Product.

Grades.—The principal grading of salmon is by species and locality. On the Columbia River an attempt is made to separate the chinook salmon into three grades on the basis of color and the amount of oil on top of the can, but very little has been done toward grading the other species.

Grading by species and locality is unsatisfactory and frequently very unjust. A system based on certain qualities and uniform for all localities is much needed.

Physical Examination.—The quality of canned salmon may be determined from three standpoints (1) the workmanship in packing, (2) the quality of the fish when caught, (3) and the condition of the fish when packed. Of these the last, of course, is the most important.

Well-packed cans should have a good vacuum, from eight to twelve inches, and should be well filled. The fish should be well cleaned and cooked sufficiently to render the bones soft and easily friable and there should be a definite salty flavor.

The quality of the fish when caught may be determined by the amount of free oil, the color of the flesh and the presence or absence of the characteristic skin markings which develop as the fish deteriorate during the spawning migration.

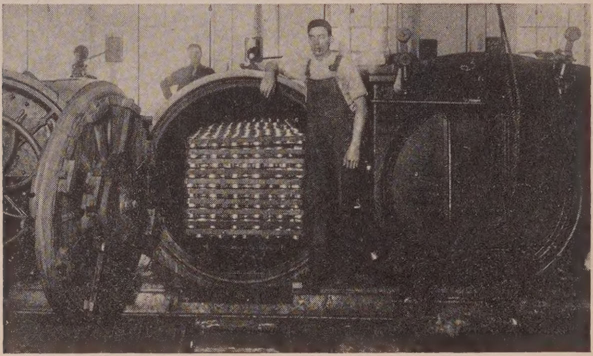

FIG. 142.—Retorts for cooking and sterilizing canned salmon.

The condition of the fish when packed is judged by certain physical signs in the canned product. Among these are odor, the appearance of an unnatural reddening of the flesh, "honeycombing," texture, and turbidity of the liquor. Canned salmon of doubtful quality, judged by odor or appearance, may be examined chemically for indol and skatol, for hydrogen or other decomposition products.

Bacteriological Examination.—A suitable percentage of the cans should be examined for living organisms. For this purpose the cans are carefully cleaned, the tops sterilized, and a part of the contents transferred to suitable media. If any microörganisms are found they are studied further in order to determine the general group to which they belong. In this manner it is often possible to tell whether further spoilage will occur, whether the organisms gained entrance through poorly made seams, or whether they resisted the processing temperature.

Composition.—Few analyses of the salmon appear in the literature. Most of the earlier ones are reviewed by Atwater and recalculated to a common basis. Other analyses have been made by Langworthy, Knisely, Loomis, Merrill, and Elliott and Clemens. Most of these analyses represent canned salmon, but Loomis also analyzed a fresh sockeye salmon.

Recently Clark and Shostrom have analyzed nearly eight hundred cans of salmon representing the five species of Pacific salmon and the steelhead trout from every important salmon canning district from Northern California to the Yukon River, Alaska. Most of the cans of salmon analyzed were prepared from the second cut of an individual fish. This was done because the composition varies in different parts of the fish, and cans from the same part may be compared better than those from different parts. A summary of the results obtained by Clark and Shostrom is given below:

TABLE 47

Average Composition of Pacific Salmon and Steelhead Trout

Species	No. Individual Fish Analyzed	Moisture	Ether Extract or Fat	Protein (N × 6.25)	Total Ash	Salt-free Ash	Calories* per Pound
		Per cent	Per cent	Per cent	Per cent	Per cent	
Chinook (king)	204	63.53	13.50	19.48	2.85	1.18	931
Sockeye (Red)	130	64.52	10.84	20.67	2.97	1.29	841
Coho	99	66.26	9.47	20.40	3.15	1.22	778
Pink..........	90	69.24	6.16	20.56	3.47	1.32	642
Chum.........	120	68.95	7.42	20.83	2.40	1.24	700
Average all species of salmon......	643	66.50	9.48	20.39	2.97	1.25	778
Steelhead trout	32	61.80	14.83	20.46	2.33	1.20	1006

* Calculated by factors of Rubner: 18.6 Cal. for 1 per cent protein, and 42.2 Cal. for 1 per cent fat, on the basis of 1 pound.

The food value of the salmon depends almost entirely upon the protein and fat. The amount of protein in the five species does not differ very much, and from a tissue-building standpoint one is about as good as another. The amount of fat differs greatly both within each species and between the different species, and so from the standpoint of energy the food value differs greatly. The chinook and sockeye salmon and the steelhead trout possess the most oil and therefore the highest food value. Many parcels of coho and pink salmon, however, have a higher food value than the average of either of the first two species, when all canning districts are considered.

The Bacteriology of Salmon.

The spoilage of fresh salmon has been extensively studied by both the Bureau of Chemistry and the Seattle Laboratory of the National Canners Association. The decomposition of mature salmon is due to a large number of species of bacteria, while the decomposition of immature and feeding salmon appears to be largely enzymic, at least in the early stages, followed by general bacterial invasion. The most common organisms isolated by Fellers and Hunter and responsible for salmon spoilage are certain species normally occurring in sea water.

Since many of these bacteria produce indol from certain amino-acids, formed from protein, this decomposition product is often formed in decomposing salmon flesh. Skatol is rarely formed, probably because few bacteria are able to produce it. Only one such organism has been isolated by Fellers, whereas no less than 30 per cent of all cultures examined from decomposed salmon were able to produce indol from salmon flesh.

No pathogenic species of bacteria has been isolated from over 600 cultures from raw and canned salmon. The time and temperature of the process employed in canning salmon precludes the possibility of survival of dangerous bacteria, such as *C. botulinum* or organisms capable of causing gastro-intestinal disturbances, unless cans are accidentally underprocessed. The heat penetration in salmon during the processing has been carefully studied in the Seattle Laboratory of the National Canners Association and it has been found that the usual process of 90 minutes at 242° F. is sufficient for preserving the canned product from future spoilage, eliminating any dangerous organisms that might have been present in the raw product, and for thoroughly cooking the fish and softening the bones.

Over 4,000 separate cans of all species of salmon have been examined bacteriologically by Fellers. In 1920, nearly 12 per cent of the cans examined were non-sterile; in 1921 this was decreased to 5 per cent, and in 1922 still further reduced to about 2 per cent. The living bacteria which are now found in canned salmon are mainly aërobic spore-formers, such as *B. vulgatus*, *B. mesentericus*, *B. cereus*, *B. subtilis*, and similar species. These are harmless saprophytes and are the common bacteria of dust and soil. The source of these organisms is believed to be the dust in unwashed empty cans, since bacteria of this type are not commonly associated with fresh salmon. This theory has been partially confirmed and is now being studied further.

The exhaust box in the cannery creates a vacuum in the cans. The vacuum inhibits to some degree the aërobic species of bacteria from developing greatly in well-exhausted cans of salmon. It has also been found that the gaseous oxygen in the can disappears in a few days and is probably held in combination by the contents, thus eliminating what free oxygen remains after the exhaust. The aërobic, spore-forming bacteria such as are occasionally found alive in canned salmon do not produce gas (i.e. swells), and although some growth may result, in general no serious spoilage takes place. A few cases have been encountered in the trade where the presence of these species in large numbers materially reduced the grade and market price of the product, though little or no decomposition could be detected by ordinary methods.

Thermophilic bacteria are not common in canned salmon, though a few species have been isolated. A good vacuum in the can effectively prevents further growth of some species of thermophiles. Strict putrefactive anaërobes are also uncommon and are seldom encountered unless the can is a "leak" or has been underprocessed. Furthermore, most species of anaërobes are prolific gas formers and cause swells. These manifest themselves within a short time after processing, and swells of this nature are usually discarded at the cannery.

Sardines.

All sardines, according to the U. S. Bureau of Fisheries, are small fish of the herring family. In California the variety used is the California sardine (*Sardinia cœrulea*); in Maine, the sea herring (*Clupea harengus*); in France and Portugal, the pilchard (*Clupea pilchardus*), and in Norway, the sprat (*Clupea sprattus*).

Canning Methods.—The canning methods used for sardines in different localities vary considerably but they consist essentially in washing, salting, cooking, drying, packing and sterilization.

In France, Spain and Portugal the fish are dried, fried in oil, and packed, while in Scandinavia a smoking process is commonly used to cook and dry the fish before packing. In the United States mechanical devices have been more fully developed in packing sardines, on account of the high cost of labor. A frying process similar to the French method is used for the highest grade of sardines, but most of the Maine sardines and many of the larger sardines packed in California are cooked by live steam and then dried.

The Maine sardine industry was started about 1875 and the industry has grown till there are now about 65 canneries scattered along the coast of Maine with an average annual output of two and a quarter million cases, about three-fourths of which contain 100 ordinary small cans and one-fourth contain 48 large or ¾ pound cans.

The Maine Industry.

The Maine sardine is prepared from the small sea herring which is very abundant along the coast during the summer and fall months. The fish are commonly taken in traps or weirs—large circular or heart shaped enclosures formed by upright stakes and netting into which the fish are diverted by barriers across their course of travel. The fish are captured by seines and transferred to power boats provided with special tanks holding usually from 10,000 to 50,000 pounds of fish. They are conveyed to the cannery through sluices and running water and are placed in strong brine for 1 or 2 hours. They are then spread mechanically on "flakes" or ¼ inch mesh galvanized wire trays and steamed in a steam box or chamber 3 to 15 minutes. The racks of steamed fish are next run into large drying chambers through which air heated by coils is drawn by means of a fan. The drying usually occupies from 1 to 2 hours at a temperature from 100-120 degrees F. The dried fish are carried on the "flakes" to the packing tables after cooling, where women remove the heads and pack them in cans, though the larger fish are often dressed on arrival at the cannery.

Oil is next placed in each can mechanically and the cans are passed through the sealing machines which attach the covers. They are then processed or sterilized by heating for 1½ or 2 hours in boiling water. The cans are usually cleaned with sawdust while hot and after cooling they

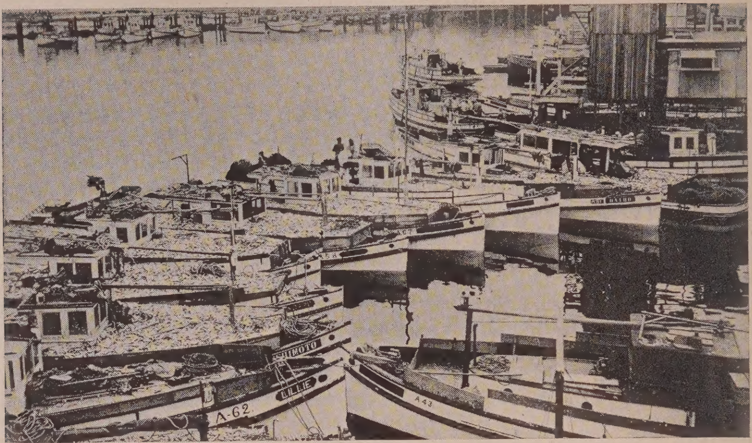

FIG. 143.—Fleet of sardine boats awaiting unloading, San Pedro, Calif.

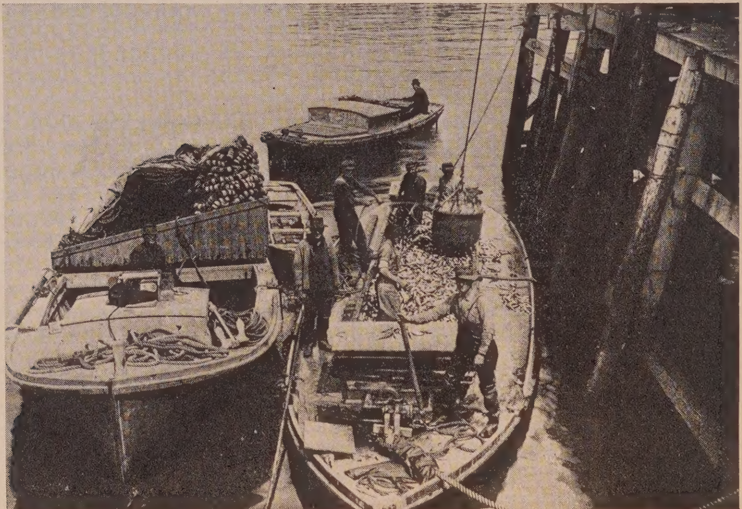

FIG. 144.—Unloading sardines.

are tested and packed in cases. In some plants pressure cookers are now being used for sterilizing purposes.

Improvements in the mechanical preparation of sardines have been made recently through the development of a machine for cutting off the heads of the raw fish, though a machine of similar type has been in use for many years by a large Maine canner, who also uses a continuous form of drier with belt conveyor. A machine has also been patented for frying the raw fish directly in the cans, but neither of these machines has yet come into extensive use.

Two types of machines for separating fish according to size are used to some extent and such separation is essential in connection with the cutting machine above referred to. The first consists of a revolving cylinder constructed of coiled pipes set at gradually increasing distances apart, and the second is a set of inclined rotating rollers, the distance between which gradually increases as the fish pass down along them.

A considerable quantity of Maine sardines are fried after partial drying of the raw fish. The frying device most used consists of a long iron tank which contains a horizontal set of steam heating coils about 8 inches above the bottom. Water is run into the tank to within an inch or two below the coils and then sufficient vegetable oil, usually cottonseed or olive oil, is added to cover the coils and give sufficient depth of oil above them to properly fry the fish in the wire baskets used to hold them. The temperature of the oil maintained in the fry bath is about 240°—260° F.

Sardines in oil constitute the large bulk of the Maine sardine pack, and for this purpose cottonseed oil is most commonly used, 5 to 6 pints being ordinarily used per case of 100-¼ tins. Considerable quantities of sardines, usually of the higher grades, are packed in olive oil. Sardines in oil are sometimes flavored with a bay leaf, clove or essential oils. About 1 gallon of oil is absorbed in the frying process for each 5-6 cases sardines fried, depending on the size and fatness of the fish.

Sardines in tomato sauce constitute a large part of the California pack, which is put up in oval tins, while Maine puts up a considerable pack of sardines in mustard sauce, containing mustard, salt, pepper, cayenne, turmeric and other spices mixed with vinegar.

California Sardines.*

The run of California sardines suitable for canning usually begins in December and continues until April. This well-defined seasonal run does not apply to the small sardines (less than 7 inches total length), the season and supply of which is very uncertain. The season for large sardines seems to be longest at Monterey; while small sardines are most plentiful off San Diego.

The packing of large sardines in California is generally quite distinct from the small sardine pack. The former are usually put up in half- or one-pound oval cans, in tomato sauce, while the small sardines, which require great care and are much more expensive to handle, are packed in oil in ¼ cans, and are regarded generally as a luxury.

* The writer is indebted to Mr. Norman Hendrickson, of San Pedro, California, for much of the information about the California sardine and tuna industries.

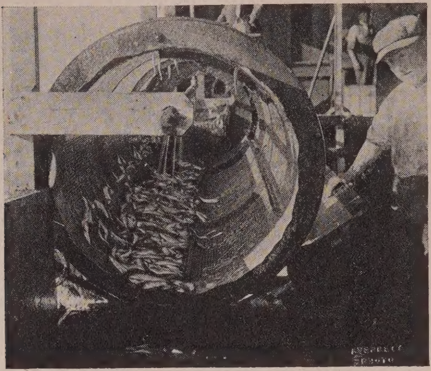

FIG. 145.—Machine for scaling sardines.

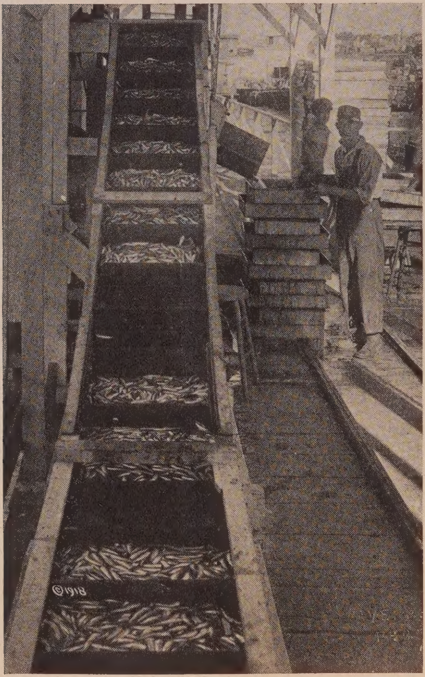

FIG. 146.—California sardines passing from drier to briner.

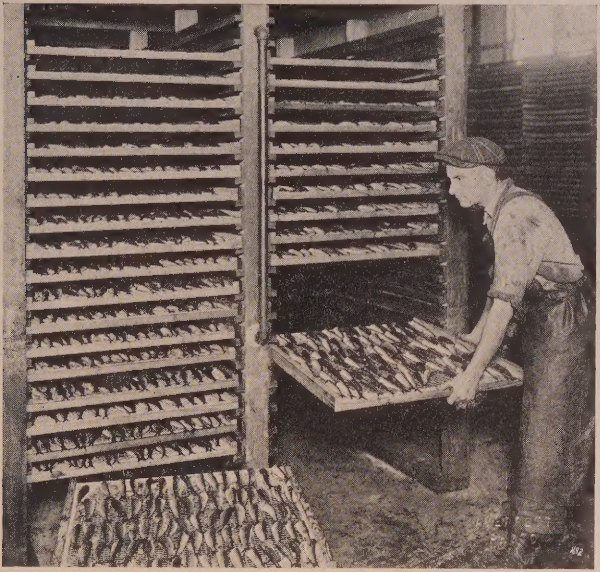

FIG. 147.—Sardine drying racks.

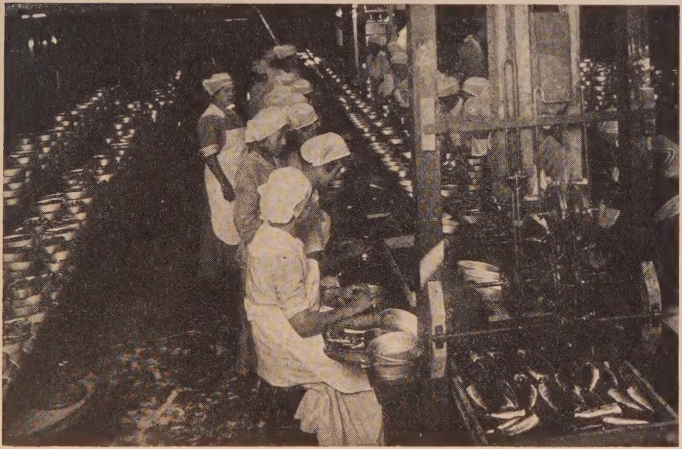

FIG. 148.—Packing California sardines.

California sardines are caught in a special form of net, known as the lampara, by the same fishermen who go out for tuna at other seasons. The fish are brought to the canneries on the decks of the boats, washed and scaled in a revolving cylindrical sieve and sluiced to the cannery, where they are beheaded and eviscerated by hand. They are then held in brine of about seventy degrees, salimeter scale, for about one hour in the case of larger fish, the strength of brine and length of salting period depending on the size of fish. The fish are then dried and fried by a process similar to that used in preparing fried sardines in Maine, though the use of continuous driers is more common than in Maine.

The fish are allowed to cool thoroughly before packing into cans. After sealing, the cans are generally sterilized or processed in closed retorts from 1¾ hours to 2¼ hours at 220° F., depending on the size of the fish. The larger sized cans are usually exhausted, that is, heated by passing through a steam box, after filling and just before sealing. This insures a good vacuum in the cans, and prevents the formation of "springers" later on.

Chemistry and Bacteriology of Sardines.

Considerable work has been done on the chemistry and bacteriology of sardines, references to which will be found in the bibliography. Of particular interest is the recent work on changes which sardines undergo in the course of preparation and storage. Weber and Wilson[2] found that on storage canned sardines show a decided quantity of volatile nitrogenous compounds, the greater part in the form of amines. The percentage of amines appears to correspond directly to the age of the product. During processing or cooking there is an increase in the amount of ammonia and amines. Storage produces gradual increase of total alkaline material due to formation of alkyl amines and a gradual decrease in ammonia.

The alkaline compound predominating is trimethylamine (which is also extensively formed in storage of herring in brine). The temperature of storage apparently has a decided influence on the quantity of volatile alkaline compounds formed. This suggests that changes may be due in some instances to bacterial growth, as anaërobic, spore-forming, gas-forming bacteria, found associated with the fish, produce both ammonia and amines when grown in fish products. This has a bearing on the detinning of cans and possibly on the softening and maturation of the product.

The principal food of the sea herring, from which Maine sardines are produced, is small animal organisms, including copepods, which constitute the so-called "red feed," and schizopods, small shrimp-like animals. With these organisms are associated certain gas-producing bacteria which have a marked deteriorating effect on fish containing feed, after they are taken from the water. The problem of avoiding trouble from so-called feedy fish of this kind is one of the most serious connected with the industry.

Herring containing feed in appreciable amounts should be held in the water for a sufficient length of time so that this food may be digested.

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[2] *J. Ind. Eng. Chem.*, *11* (1919), 121.

This can usually be done with herrings taken in weirs, but fish captured with seines, and at certain seasons, even fish taken in weirs, often contain so much feed that it is impracticable to prepare sardines of good quality, particularly from the small fish, unless they are promptly taken to the factory and eviscerated.

Oil for Sardines.

Flanders and Allison[3] have made an interesting study of commercial olive and cottonseed oils used in the canning of Maine sardines. Sixteen samples of olive oil and twenty-two samples of cottonseed oil were included in this study. In testing olive oil for this purpose they found the most valuable information could be secured from the determination of acidity, appearance and flavor. This does not include tests for adulteration with other foreign oils, for which special chemical or physical tests must be applied.

In the case of cottonseed oil, the most helpful tests for quality were the determination of the amount of sediment at 22° C. (71.5° F.), and the "cloud test" which consists essentially in heating the oil sample to 150° C. (302° F.) and cooling down at once to the point where the cloud appears in the oil. Oils which show sediment at room temperature showed clouding temperatures of not lower than 0° (32° F.), while the best oils gave results of — 4° C. (23.8° F.) or lower.

As a result of this study, Flanders and Allison recommended the following specifications for olive oil and cottonseed oil for packing sardines:

Olive Oil.—To be light colored, free from sediment, sweet in taste (not rancid), it shall show less than 1% acidity (calculated as oleic acid), it shall be guaranteed free from adulteration.

Cottonseed Oil.—Summer Oil: Shall be sweet in taste (not rancid)—free from sediment at 70° F. and shall show a "cloud test" not higher than 30° F. when tested by the method approved by the American Chemical Society.

Cottonseed Oil.—Winter Oil: Shall meet the above requirements except that it shall be capable of withstanding a "cloud test" of 21° F.

The composition of various types of Maine sardines is given in Table 48.

Norwegian Sardine Canning.

The canning center of Norway is Stavanger, where some of the largest canneries are located, and which is the principal shipping point for Norwegian canned fish.

In 1917 there were about eighty canneries in Norway putting up sardines and herring. The canning season lasts from about June 1st to December 1st, while fish balls and other products are put up when the canneries are not busy canning the fresh fish.

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[3] Unpublished report, Maine Sardine Inspection Laboratory, National Canners Association, 1920.

TABLE 48

Analyses of Maine Sardines

Commercial Samples Packed during 1916 and Analysed by H. M. Loomis and E. S. Middleton, National Canners Association.*

	Solids and Oil	Oil (Ethyl Ether Extract)	Protein	Ash	Salt
	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Steamed sardines in oil— Average of 8 samples	47.85	25.52	19.17	3.84	1.54
Fried sardines in cottonseed or olive oil— Average of 8 samples	49.33	27.20	18.75	3.86	1.59
Smoked sardines in oil— Average of 2 samples	56.76	30.97	20.19	5.18	2.41
Sardines in mustard sauce— 1 sample	29.63	7.55	18.02	3.37	1.19
Sardines and herring in tomato sauce— Average of 3 samples	32.33	5.55	18.08	3.94	1.43

* From Annual Report of Director of Sardine Inspection, National Canners Association, 1919.

Following is a description of the canning process, as given by United States Consul M. P. Dunlap in 1917:

> The fish used for the canning of Norwegian sardines is that known in Norwegian as "brisling" and in English as "sprat" (genus, *Clupea sprattus*). A lower grade of sardine is put up from the small herring or "mussa" (*Clupea harengus*) or from a mixture of these with brisling. These fish are from 3½ to 5 inches in length.
>
> The summer fishing season lasts from about June 1 until October 15. During this season the brisling or mussa are caught in the fjords where they are driven by the whales. They are caught by large seine nets, which are carried out around the fish by small boats. As this is the spawning season the fish are left in the nets three days before being taken out of the water, so that their condition may be perfect for canning.
>
> The first thing done with the fish in the canning factory is to put them through a thorough washing process in large tubs. They are then placed in other tubs in brine. After remaining in the brine from 20 minutes to a half hour they are taken to another department and placed on tables. Here they are placed in long rows of little grooves in which a wire rod is run through the eye of each fish. Each rod, with 22 fish on it, is then hung on a flat frame, 30 rods on each frame, making 660 fish on a frame. Ten of these frames are then placed one above the other, with the 6,600 fish hanging from them, in a crate or larger frame. This is wheeled into one of the many smoking ovens, where the fish are smoked for 30 minutes or so, the length of time depending upon the condition of the fish. They should be lightly smoked and cooked, but not enough to brown them, as the fine silvery finish must be retained for canning.
>
> The fish are then taken from the smoking ovens to the cutting machine, where their heads are cut off. The fish are then sorted by hand ready for packing in the cans in uniform sizes. A small quantity of olive oil is deposited in each can by a machine. Girls then pack the fish in the cans by hand.
>
> Before the lid is put on the can it is put through a machine that places a small rubber band inside the lid. The lid-fastening machines then clasp and hermetically seal the lid on the can. No solder is used in covering and fastening the lids nor in

making either lids or cans. The cans are then sterilized by intense heat, varying according to the size of the can. Later the cans are labeled, the key inserted, the tins wrapped in paper and packed 100 to the case. For all fish not packed in oil, tins lacquered inside are used. This is to prevent corrosion of the tin. The oil of itself prevents corrosion.

The French Sardine Industry.

The French sardine is prepared from the pilchard (*Clupea pilchardus*), which is caught extensively off the west coast of France and Portugal. The fish are taken in nets, being attracted to the fishing grounds by the use of cod roe as bait. The season for pilchards is from May to September. The fishing is generally a separate business from the canning, the canners buying their supply of fish from fishermen.

On arrival at the canneries, they are sprinkled lightly with salt and the head and viscera removed by hand. They are immediately transferred to strong brine for ½ to 1 hour, after which they are put into wicker baskets and washed. The drying operation is the next step, the fish being arranged vertically tails up, in special wire-meshed trays and dried in the open air, except in damp or rainy weather when artificial heat is generally used. When sufficiently dried, the fish are fried in the same trays by immersing them in tanks of hot oil. Peanut oil is often used for frying as well as olive oil. The time for frying depends on the size and dryness of the fish, but usually is about 2 minutes. The surplus oil is allowed to drain off on a sloping table and after cooling, the fish are packed in the cans, usually in olive oil or peanut oil. The covers (in this case the bottoms) of the cans are soldered on by hand, the can being revolved on a small turn table operated by the foot. The cans are processed by immersion in boiling water for 2 hours.

Various essential oils and other ingredients are used to give added flavor to French sardines, such as oil of lemon, cloves, bay, truffles and pickles.

French sardines are put up in cans of a large variety of sizes and shapes. The standard type is the "quarter" can which usually holds from 8 to 14 fish. The "half" can is twice as large as the "quarter" and the "eighth" one-half as large. Oval and oblong cans of special design are also common.

The quality of sardines depends largely on proper salting and cooking, though the character of the oil used is also very important. The fish should be uniform and of medium size to make the best product.

With the falling off in the sardine production in France due to the diminishing supply of fish, the production of Spanish and Portuguese sardines has increased, some of which are not inferior to the French product.

Tuna.

Canned tuna is an important product of Southern California. The industry began about ten years ago and now averages approximately 600,000 cases or 15,000,000 pounds per year. The only other places where tuna is canned on a commercial scale are Sicily and Hawaii.

The Sicilian tunny industry in carried on along the northern coast of the island during May and June. The amount canned, according to

Consular Report in 1912, varies from 3,000,000 to 7,000,000 pounds a year, in cans varying from ½ pound to 4 pounds in capacity. The refuse from the canneries is boiled 24-28 hours, and is pressed for the recovery of tunny oil which forms a by-product of considerable value. The press cake is used locally as fertilizer.

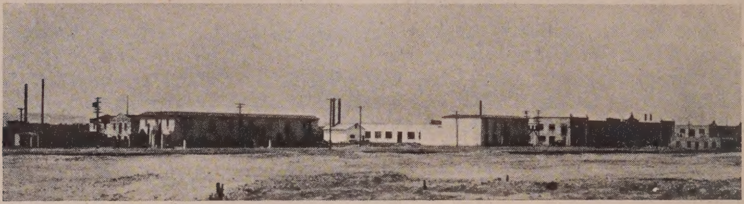

Fig. 149.—Southern California fish canneries.

There are about 38 fish canneries in Southern California, in most of which tuna are canned when a supply is available. When tuna are no longer caught, the canneries are generally busy putting up sardines. Most of the plants, being comparatively new, are modern in equipment and sanitation.

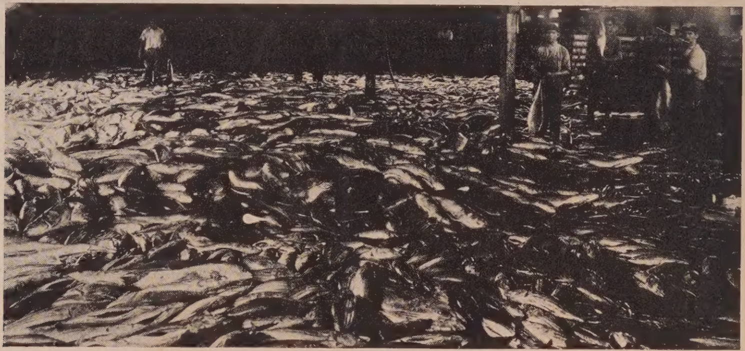

Fig. 150.—Tuna on floor of cannery.

The tuna canning season usually begins in June and is at its height in July and August, the fish working northward from San Diego as far as Santa Cruz Island.

The four species canned as tuna are:

Species	*Common Name*
Germo alalunga (*Thunnus alalunga*)	Albacore, Tuna, Long-finned tuna.
Thunnus thynnus	Tuna, Bluefin tuna, Leaping tuna.
Germo macropterus, or *Germo germo*	Tuna, Yellowfin tuna.
Gymnosarda pelamis (*Euthynnus pelamis*)	Striped tuna.

The tuna for canning was at first only the product of the albacore, known as "white meat tuna." During the past five years, however, the supply of albacore has become insufficient to meet the demand for the canned product. Consequently, increasingly large quantities of other varieties have been packed, including the closely related species known as yellowtail or amberfish, and bonito.

The albacore are caught from motor boats, using a hook and line baited with live bait. The fish average about thirty pounds in weight. Bluefin and yellowfin tuna are usually caught with purse seines handled from boats. They range in size from about 20 up to more than 200 pounds weight, averaging about seventy pounds. Striped tuna are caught both by hook and line and by seines, and average about 15 pounds in weight.

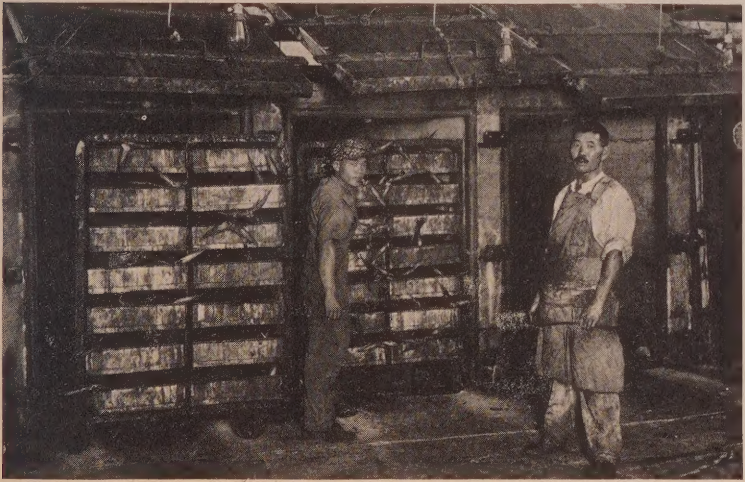

Fig. 151.—Cooking California tuna before canning.

Tuna are gutted and washed before delivery to the canneries. On the conveyor from the wharf to the cannery they are again washed by sprays, then placed in baskets, belly downward, to drain off the blood and keep the meat white. They are run on racks into large steam chambers or cookers. The cooking time is usually from 2½ to 4 hours at 212-216° F., depending on the size and condition of the fish. The racks are then run out and allowed to cool in an air current for at least twelve hours, or until the flesh has become firm enough to handle without breaking up. The fish are then easily skinned and beheaded, and separated into four longitudinal sections. After the removal of the dark meat, the strips of white meat are cut into proper lengths to fit the cans, into which they are packed, and salt and oil are added mechanically. Cottonseed oil is commonly used, ¾-1 ounce for each No. ½ (7 oz.) can. The dark meat is also canned to a considerable extent, but does not command so high a price as white meat tuna.

In order to heat the cans and get a better vacuum after sealing, many canners pass them through an "exhaust box," an enclosed steam chamber through which a conveyor runs, after which the cans are immediately sealed.

Closed horizontal retorts are generally used for "processing" or sterilizing the canned tuna, the usual process temperature being 240 degrees F., the time averaging from fifty minutes for No. ¼ cans, fifty-five minutes for No. ½ cans, to seventy minutes for No. 1 cans.

To prevent damage to the cans by too sudden release of external pressure when retorts are opened, the cans are usually cooled under pressure by introducing compressed air and water into the retorts before opening.

Methods of canning yellowtail and bonito are very similar to those followed for tuna.

Recently there has been considerable demand for California tuna packed in Italian style. Bluefin tuna (or striped tuna) is used for this product, which is more heavily salted than the regular canned tuna and is packed in olive oil.

Canned Mackerel.

In Maine, after delivery at the cannery, the mackerel are dressed by splitting, removing heads, tails, fins, and viscera, and washing. The fish are next held in strong brine until the desired saltiness is secured, and then are packed and sealed in oval cans, usually with a little vinegar and spices. The sealed cans are cooked and sterilized in boiling water.

On account of the great demand for fresh and salt mackerel and the comparative scarcity of the fish in recent years along the Atlantic Coast, few mackerel are now canned on that coast. However, the canning of the chub mackerel (*S. japonicus*) on the coast of California has developed to considerable importance, these fish having been first canned experimentally by the tuna canners of southern California.

The California method of canning consists of the following steps:[4] The fish are scaled, eviscerated and the head and fins removed. The dressed fish are then put into brine about 75° salimeter scale, until blood is extracted, rinsed in fresh water and packed tightly in oval cans. The full cans are then inverted on wire mesh racks and cooked in retorts with live steam for 45 minutes at 3 pounds pressure. After draining about 30 minutes, the cans are reversed, the backbones of the fish removed, the cans repacked and about ½ ounce cottonseed or other vegetable oil added. After exhausting the cans for about 10 minutes at 212°, the cans are sealed and processed 1½ hours at 240° or 2 hours at 230°.

Canned Herring.

Large herring are canned plain or kippered to some extent in Maine, on the Pacific Coast, and in Great Britain, the methods used being similar. Other canned herring products are put up in European countries bordering on the North Sea.

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[4] Cobb, J. N., Canning of the Fishery Products. Seattle, 1919.

In Maine, herring running 10 inches or more in length are used for plain canned herring. The fish are beheaded, dressed and held in strong pickle (70-80°) for about one hour. They are then packed vertically in tall one pound cans, are steamed in retorts 30 minutes at 230° F., and, after sealing hot, are processed two hours at 240° F.

Kippered Herring.—The fish are dressed and pickled in brine as for plain herring. They are next strung through the tails on wooden rods about ½ x ½ x 24″ through which long nails are driven a few inches apart. These sticks are placed close together in horizontal rows on frames built in a smoke-house and these rows extend one above the other to the top of the building and to within about 6 feet of the floor. The fish are exposed to the smoke and heat from a smoldering fire of birch or other hard wood for 18-24 hours, which dries them and gives them the slightly smoky flavor desired. The fish are then removed and packed by hand in one pound oval cans. The cans are sealed without any further addition and are processed in a boiling water bath for about 2½ hours.

Marinated Fish.—Bismarck herring[5] are prepared by washing choice herring of uniform size in a revolving cylindrical screen which also removes scales. The fish are then dressed by removing heads, tails and bones by hand, rinsed and placed in about 75° brine for 2 or 3 hours. From the brine tanks they are transferred to a vinegar pickle of 5-6 per cent acidity, containing considerable salt. After about two days the fish are ready to pack in cans, in which they are placed in layers, with onions, peppers and mustard seed on each layer. A small amount of 2¼ per cent vinegar and a little sugar is added to each can, which is exhausted, sealed, and processed.

Rollmops is prepared by spreading the boned and pickled herring on a table and rolling each piece around a piece of salt cucumber pickle or onion. The rolls are fastened with wooden pins, packed in cans, and after adding peppers, allspice, mustard seed, bay leaf, paprika, and a slice of pickle, a little vinegar is added and the can is exhausted, sealed and sterilized.

The preparation of marinated fish, rollmops and other miscellaneous products is described in greater detail in Chapter 20, Miscellaneous Processes of Preservation.

Shad.

The shad is so highly esteemed in the fresh state and the supply on the Atlantic Coast has been so limited in recent years that it is not canned there. This fine food fish was introduced on the Pacific Coast about 50 years ago and has become well established in the Sacramento and Columbia Rivers, where it is caught to a limited extent by the salmon fishermen when salmon are not plentiful, and is canned by a few of the salmon canners.

The fish are scaled, split and dressed. After thorough cleaning they are cut in pieces transversely to fit the one pound tall salmon can in which they are usually packed. Cans are exhausted about 4 minutes and processed at 240° F. for 80 minutes.

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[5] Stahmer, M., Fischhandel und Fischindustrie. Stuttgart, 1913.

Fish Flakes.

A canned product of considerable importance has been developed in recent years on the New England coast through the use of the cod and haddock, for the canning of fish flakes. The fish prepared in this way resemble much more closely the fresh fish than do foods prepared from the dry-salted fish.

The fish are dressed, cleaned and then held in large tanks under brine to extract the blood and give the fish the desired flavor. The time in brine depends upon the form and size of the fish. Upon removal from the brine the fish are skinned and the napes carrying the fine bones are removed.

The fish are then placed on trays and run into retorts where they are cooked by live steam until tender. They are then removed from the retort, carried while cooling to the packing room where backbones are removed, the tender meat of the fish broken up into flakes and packed into cans. The cans are exhausted for about 10 minutes at 212° and after sealing are processed at 240° F. There are two sizes of cans used, one containing 7½ ounces fish and the other 11½ ounces. The cans are lined with parchment paper to prevent discoloration.

Fish Roe.

The canning of fish roe has formed a considerable industry in Russia where the roe of two species of sturgeon is converted into the highly-prized black caviar of commerce.

Of late years, this industry has greatly declined both on account of the scarcity of the raw product, and the unsettled conditions in that country. Imitation caviar is put up in considerable quantities in Germany and the United States from the roe of other fish.

River herring roe is canned to a limited extent on Chesapeake Bay, and shad roe on the Columbia River. The following[6] is a description of the process as practiced on the Chesapeake Bay:

> Herring roe intended for canning is collected in buckets as the fish are cut and washed in fresh water in special trays, blood and adhering particles of entrails being removed. The roe is then put in the cans. As it swells considerably in processing, the cans must not be entirely filled. If of the sanitary type, the cans are filled to within about three-fourths of an inch of the top with roe and then filled to the edge with cold salt brine, about 1 pound of salt to 8 or 10 gallons of water being used to make the brine. The brine is added solely for seasoning. The cans are immediately capped and placed in the processing baskets. If solder-top cans are used, the filled cans are placed in the exhaust box (about 10 minutes). Upon removal from the exhaust, the necessary air space is provided for by pressing the roe down with a plunger. Material clinging to the groove where the solder is to be applied is removed with a brush and the cans are capped and tipped. The canned roe is processed in a closed kettle for 45 to 55 minutes at a temperature of 240° to 245° F. (for No. 2 cans). The milt roe may be canned in the same manner as the roe, except that the cans can be more completely filled, as this product does not swell in the processing. As the quantity of brine used in this case will be somewhat less, it should be made correspondingly stronger.

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[6] *Bureau Fisheries, Rept.* 1917, 45.

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Chapter 20.

Miscellaneous Processes of Preserving Fish.

Variety of Products.

The principal processes of fish preservation are those of canning, salting, smoking, and drying. In America, very little fish is preserved by other processes. In Maine, some herring is lightly salted and then pickled in a brine containing vinegar according to a process generally known as marinating. These fish are sold chiefly to Europeans living in New York and other large cities. Recently, many novel canned fishery products have appeared on the American market, but the primary means of preservation of these products is sealing in tin or glass and subsequent sterilization (canning), therefore these products are considered in the section on canning of fish (Chapter 19).

But in Europe, where the inhabitants are more dependent upon food from the sea, vinegar, spices and other preservatives are commonly employed for the preparation and preservation of various fishery products. To obtain finely flavored products, vinegar is often used as a preservative in combination with salt, spices, etc. Fish are often fried in oil before being preserved in spiced vinegar. Slightly salted fish are sometimes preserved in vinegar. Meatless sausage is made by substituting fish for the meat.

In Japan and the Philippine Islands, where the people are still more dependent upon sea foods than in Europe, fish are conserved in almost every conceivable manner. Various fermented products such as bagoong are prepared. Fish are pickled in hot pure or spiced vinegar, without salting. The flesh of sharks is utilized for the preparation of shark-flesh paste. Fish puddings are prepared, often being flavored with alcoholic liquors.

Many of these unusual products might be successfully introduced in America. Some of them are sold in small quantities in New York City, where the foreign population is very large. The difficulty lies in the cost of an advertising campaign of sufficient extent to familiarize the public with the value of novel products.

Fish Pickled in Vinegar or Marinated Products.

Max Stahmer, the author of *Fischhandel und Fischindustrie,* defines all fish as marinated which have been given some method of preparation and then soused in vinegar sauce. The fish are prepared for the vinegar pickle either by baking and frying or by salting in either salt brine or brine containing some vinegar. In southern Europe, marinated fish are considered those which are fried in hot oil and then packed in spiced vinegar. While some marinated fish are packed in America and Great Britain, the industry is centered chiefly in Continental Europe, especially in Germany.

The finest German marinades come from the Pomeranian and Prussian coasts, from Stralsund, Rügen and Danzig. Important marinade factories are located in Berlin, Altenburg, Krefeld, Cologne, Bohmen, Geestemunde-Bremerhaven and Hamburg-Altona.

The principal raw material in Germany used for marinating is herring, although haddock, anchovies and other fish are used to a limited extent.

Principle of the Use of Vinegar.

Acetic acid is the active principle of all vinegars and the component which gives them their antiseptic properties. Vinegars differ from each other in flavor, color, and aroma because of the presence of small amounts of other organic compounds whose nature depends upon the source of the vinegar. The higher the percentage of acetic acid the greater the preservative power of the vinegar; about 15 per cent of this acid is required to stop bacterial growth. Since only the very strongest vinegars contain this much acetic acid, it is evident that weaker vinegars are not able to preserve fish indefinitely in open containers. However, vinegars containing five per cent or more of this component will retard spoilage for weeks and perhaps months if the fish are kept in cool rooms.

Russian Sardines.

A considerable quantity of small sea herring or Russian sardines are prepared in Germany and Russia, and to a small extent in America, by first salting the fish in strong salt brine, then cleaning, and pickling in spiced vinegar. The small fresh, round herring or sardines are placed in saturated salt brine until they are thoroughly salted; this requires about ten days' time. The salted fish are then beheaded, eviscerated, and washed in fresh water. After draining, the cleaned fish are assorted as to size; then the various sizes are packed separately into kegs or other containers. After various spices are added, the kegs are filled with vinegar. The spices sometimes used include the following: allspice, chile pepper, cloves, ginger, coriander seed and capers. Bay leaves, onions, and horse-radish are also used to flavor the pickled fish. Stevenson[1] gives the following proportions of materials required for the preservation of 120 pounds of fish by this method: Vinegar, 2 gallons; allspice, 1.5 pounds; sliced onions, 4 pounds; sliced horse-radish, 2 pounds; bay leaves, 2 pounds; cloves, 0.5 pound; ginger, 0.5 pound; chile pepper, 0.5 pound; coriander seed, 0.5 pound; capers, 2.5 ounces. Fish prepared in this manner should be kept for a week to a month before being marketed. Such pickled sardines will keep for a year or more if stored in a cool place.

Fried Marinated Fish.

A considerable quantity of fish are preserved in Europe by first frying in oil and then marinating. Young herring, sardines, anchovies or any small food fish may be preserved by this process. The fish are cleaned, washed, and then dried for about an hour in the open air. After drying the small fish are fried in hot oil, cooled and allowed to drain. The fried fish are packed in barrels, kegs, glass jars or other containers and covered with hot spiced vinegar containing some salt. After standing for a short time, the containers are closed and the fish are ready for shipment. Fish preserved in this way will keep for a long period if strong vinegar is used for preparing the pickle.

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[1] *U. S. Fish Comm., Bull. 18* (1898), 467.

Bismarck Herring.

The Germans consider the true marinated fish to be only those which are cured with strong salt and vinegar pickles without cooking. Examples of the German products are the Bismarck herring, mustard or Kaiser-Friedrich herring and Russian sardines. The most important of these are the Bismarck herring and the Russian sardines. A few American packers have realized the demand for these products and have packed limited quantities but the chief industry is in Germany and Russia.

In Germany, the Bismarck herring are prepared from herring of a uniform size. The fish are first washed in a special washing machine consisting of a large revolving drum equipped with spray of water. The washed and scaled fish are then cleaned, beheaded and boned by women. Boning machines have been tried out by some of the larger factories but because of the difficulty arising from the lack of uniformity in the size of the fish the machines have not been successful. The boned fish are rinsed with water and brushed inside to remove the black lining of the belly cavity. The cleansed fish are then placed in salt brine for two or three hours. The slightly salted fish are put into a vinegar pickle (5 to 6 per cent acetic acid) containing a moderate amount of salt. After remaining in the pickle for two days, the fish are removed and placed on large tables in the work room and packed tightly in boxes with a slice of onion, some pepper and mustard seed. A vinegar sauce (2.2 to 2.4 per cent acetic acid) containing some sugar is added, the box is closed and wrapped. The herring are usually shipped immediately, but if they are stored, are kept in cool dry rooms.

Mustard or Kaiser-Friedrich herring are prepared in exactly the same manner as Bismarck herring except that a mustard sauce is added when the fish are packed instead of the sweetened vinegar. The mustard sauce is usually prepared in special factories and is merely thinned preparatory to use in the marinating factory.

Other marinated fish are prepared by the addition of Remoulade, wine, bouillon, tomato, or Cumberland sauce to the vinegar prepared fish. Another favorite marinade is prepared by the use of a sauce prepared from the milts of the herring. In cutting the herring, the milts are collected and mixed with vinegar sauce. When desired for use, the milts are strained through a sieve so that the membranes are removed. As the herring are packed in the boxes, black pepper, pimento, onion, cloves, bay leaves and other spices are sprinkled over each layer. The combination of spices used depends upon the individual taste of the packers. The milt sauce is added to the packed and spiced vinegar prepared fish; the boxes of herring are closed and wrapped as in the case of the plain Bismarck herring.

The marinated product "rollmops" is prepared by rolling the boned and vinegared herring with a slice of cucumber pickle or onion. The roll is fastened on two sides with a small wooden pin or "skewer." These rolls are packed in boxes and covered over with cucumber pickles, shallot, bay leaf, paprika, pepper, pimento, and mustard seed. Vinegar is finally added and the box is covered and wrapped. When fresh herring are very scarce or very dear, rollmops are prepared from salt herring. In this case the salt fish are freshened, washed and boned, and then placed in the vinegar pickle, which need not be as strong as when fresh herring are used, since the fish are already cured. Salt herring usually make an inferior quality of marinated product.

Japanese Pickled Fish.

The Japanese pickle fish by a very simple process. The fish are merely cleaned, washed and then placed in jars or kegs and covered with either pure or spiced vinegar at, or nearly at, the boiling point. To keep such fish in warm weather they must either be pickled with very strong vinegar or kept in cold storage.

Fermented Fish Products.

A fermented fish product called bagoong is one of the most common fish products of the Philippine Islands. Seale[2] has described the native process of manufacture of this food as follows:

> It is prepared by mixing 2 parts of young or small fish—anchovies preferred—with 3 parts of salt. This is placed in stone jars, covered to exclude flies and dirt, and allowed to ferment for 1 month. It is then ready for use, the liquid portion being used as a sauce and the solid fried or mixed with eggs.

Anchovy Paste.

Anchovy paste is another European product of much importance. Saltpeter is the chief preservative used in its preparation. Sherrin[3] gives the following directions for making paste from a peck of anchovies:

> Two lb. common salt, 3 oz. bay salt, 1 lb. saltpeter, 2 oz. sal prunella, and a few grains of cochineal, pounded together in a mortar; into a stone jar place first a layer of fish, then of the pounded ingredients, and so on until the jar is filled; press them down hard and cover closely. After six months they will be ready for use.

Fish Sausages.

In Germany, Norway, Denmark and other countries of northern Europe, sausages are prepared in large quantities from mixtures of fish, fish liver, seal meat, crab meat, fish roe, pork, flour and various condiments and sold as various kinds of fish sausage. The flesh of the fish,

[2] *Philippine J. Science, 9* (1914), Sec. D, 1-17.

[3] Handbook of the Fishes of New Zealand, Auckland, 1886.

crab, etc., is ground finely with pork, flour, and spices and the product is either canned with sauce, or stuffed into sausage casings, and either sold raw or smoked. Before the World War, the sausage mixtures consisted of relatively large proportions of pork, but because of the scarcity of meat during the war, the proportions of pork became smaller and smaller, and in many cases the sausages contained no meat at all. Before the war, little flour was used in the sausage mixture but considerable quantities of flour were later introduced into the mixture to replace in part the deficiency of meat. Large quantities of these meatless fish sausages were consumed by the German army both in the field and in the camps and hospitals. In some cases, no fresh fish flesh was used in the manufacture of these sausages, this being replaced by salted fish, dried fish, fish roe, fish liver and the like. Other ingredients occasionally used in the preparation of these sausages include oysters, mussels and other shellfish.

Christiania Anchovies.

Christiania anchovies are prepared by packing slightly salted fish in spiced brine. The fresh sprats are immersed in weak brine for 12 to 18 hours, about 15 pounds of salt being used for each 100 pounds of fish. At the end of this period, the fish are drained and loosely packed in a barrel with the following ingredients,[4] which have previously been finely crushed and well mixed: 4 pounds of Luneburg salt, 6 units of pepper, 6 units of sugar, 6 units of English spices, 1 unit of nutmeg, and 1 unit of Spanish pepper. After 2 weeks the anchovies are repacked tightly in barrels or kegs, being carefully arranged in layers with backs downward. A quantity of the ingredients above mentioned is sprinkled over each layer with the addition of a few bay or cherry leaves. The barrels or kegs are filled with brine and then coopered; they are turned daily for the first few days and then every other day for two or three weeks.

German Delikatessen (Anchovies).

In Sweden, Finland and Germany, many anchovies and small herring are preserved by packing in salt, sweetened and flavored with sugar, saltpetre, pepper, cloves, mace, cinnamon, ginger, sandalwood, Spanish hops, bay leaves, etc. In Finland, the sprats or anchovies are thoroughly washed and are packed in the round condition, but in Sweden the fish are eviscerated, beheaded and thoroughly cleaned.

The procedure in packing the fish as described in a consular report is given below:

> The salt, sugar and saltpetre are first weighed out and thoroughly mixed together, then the other ingredients are weighed and thoroughly mixed with the salt and sugar. . . . Some of the spice mixture is strewn on the bottom of the one-liter tin, then a layer of herrings, in rows, is placed upon it, with the backs of the fish downwards and the mixture strewn over it; another layer of herrings is laid down in the same way, the rows being placed obliquely across the rows in the layer below, and so on, not more than four layers being laid down in the one-liter tin. One whole bay-leaf is placed at the bottom, one between each layer, and one on the top.

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[4] C. H. Stevenson, "Preservation of Fishery Products for Food." *Bureau Fisheries, Bull. 18* (1898), 468.

The lid is then put on, and for local use made airtight with paraffin wax. The tins, after being closed, are placed in a cool place, preferably in an icehouse; it is said that there is no comparison between the product left to ripen in a warm room and that ripened in a cool place.

A few of the preservative and spicing mixtures recommended are given below:

	A Grams per Liter Tin	B Grams per Liter Tin	C Grams per Liter Tin
Luneburg salt	125–150	150	....
Liverpool salt	....	....	150
Sugar	50	100	100
Saltpeter	1.5	2	....
Jamaica pepper	3.5	....	4
Black pepper	1	2	3
Cayenne pepper	....	....	0.04
Cloves	1.5	1.5	2.0
Mace	1.0	....	1.0
Sandalwood	....	1.0	1.0
Cinnamon	0.5	....	1.0
Ginger	0.5	1.0	2.0
Spanish hops	....	1.0	2.0
Bay leaves	1.5	2.0	2.0

The anchovies are usually packed in kegs but cans are highly recommended. Only the fatter fish are used as lean fish produce an inferior product.

Caviar.

American Processes of Manufacture.

Caviar in the strictest sense of the word is the prepared roe of various species of sturgeons. Recently, the roe of various other species of fish has been used for the making of caviar, for the supply of sturgeon roe has diminished to the point where it is entirely inadequate to meet the demand. The species of fish, other than sturgeons, whose roe is sometimes used for the making of caviar include the following: spoon-bill cat or paddlefish, salmon, whitefish, lake herring, carp and cod.

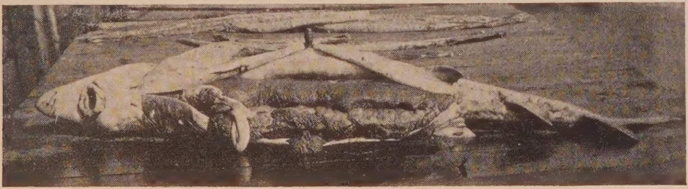

FIG. 152.—Sturgeon cut so as to show roe from which caviar is prepared.

Only a comparatively few years ago the sturgeon was a very common fish in American waters. However, when caviar and smoked sturgeon became popular, the price of these products rose rapidly and fishermen found that sturgeon fishing was a very profitable occupation. As a result the waters were overfished, and now the sturgeon has been nearly exterminated. Because of the scarcity of these fish little caviar is prepared in the United States. In practically all cases, the fisherman who catches the female sturgeon prepares the caviar and either sells it to the local buyer or to a buyer in one of the nearby wholesale markets.

In preparing the caviar, the sturgeon roe, immediately after its removal from the fish, is placed on a four-mesh sieve over a large mixing tub. The roe is rubbed back and forth on the sieve until the eggs pass through, leaving the membranes and connective tissue on the sieve. About 1 pound of Luneburg salt or one-half pound of American dairy salt is sifted on to each 12 pounds of eggs. Luneburg salt is a German salt that has a particular flavor desired in caviar. Immediately after the addition of the salt, the mass is thoroughly mixed. At first the mass is sticky, but enough water is soon abstracted from the sturgeon eggs to dissolve the salt and form a brine. The mixing is continued for 5 to 8 minutes after which the mixture is allowed to stand ten minutes or longer. The eggs are then poured into sieves holding 8 to 10 pounds of caviar and allowed to drain for about an hour. The caviar is then poured into kegs and shipped to the canning factory where it is placed in cans or jars which are sealed and pasteurized.

Caviar Manufacture in Russia.

The preparation of caviar is a matter of much importance in Russia. The most highly prized caviar is made from sturgeon roe. Since the sturgeon fisheries of Russia are much greater than those of America much more sturgeon caviar is prepared in that country. Roe from the pike-perch (*Lucio perca sandra*), the Caspian roach and the bream is also extensively used for a preparation known as scaled fish caviar. The methods used in Russia are much the same as those employed in America except that comparatively little is canned and much is prepared specially for export by pressing. Pressed caviar contains less water than the ordinary product and consequently keeps better.

Borodin[5] has described the modern methods of caviar manufacture employed in Russia as follows:

> Preparation of fresh grain caviar follows:
>
> Captured female sturgeon full of roe are killed by a blow on the head or the nose. They are put on the border of a coarse sieve over a large wooden tub. The sieve is quadrangular, having four wooden borders, on which a net is spread which is made of thick yarn without knots, with meshes about one-eighth of an inch apart. The belly of the fish is cut with a sharp knife, making a long cut beginning at the pectoral fin and ending at the anal opening. They remove the roe, consisting of grain-shaped eggs bound together by means of the tissue. A portion of the roe is taken and put on the above-named sieve and rubbed by the palm of the hand in order to separate the eggs from the tissues. The separated eggs fall through the meshes

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[5] *Fishing Gazette, 37* (1920), No. 9, 10-11.

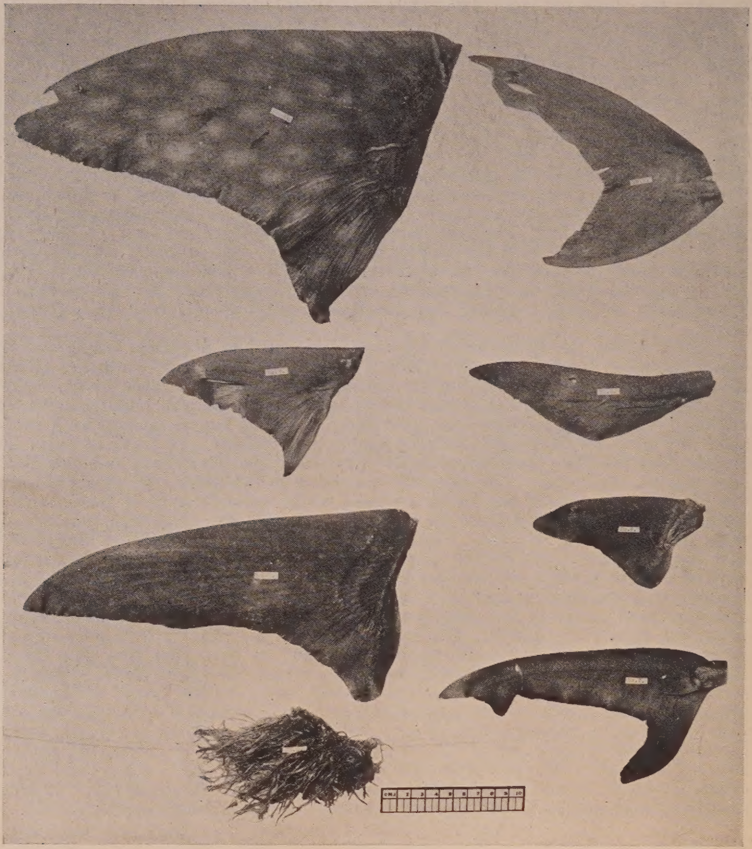
of the sieve down into the tub below, while the tissues remain on the sieve, and after the operation with a portion of the eggs is finished, they are thrown into a bucket. The operator should not rub the roe too hard, because in this case the eggs may be injured and the caviar will not have its regular appearance.

When the whole roe is already passed through the sieve and gathered in the tub, it is salted with a dry salt in preparation, during the warm summer time 4 pounds of salt to 36 pounds of roe (1-9), and during the cool fall or early spring time 1 pound of salt to 36 pounds of roe. When salting in such a manner, the best fresh (that is to say, mildly pickled) real Russian caviar is obtained. The salt is mixed slowly and thoroughly with the roe, using an oar-shaped pail, and left in it, say, from 5 to 8 minutes. Afterwards the salted roe is taken by portions from the tub and poured on the fine meshed wire sieves (for about ten pounds each). The meshes of these sieves must be about the same as those ordinarily used in flour sifters. Drained from the pickle, the roe becomes a ready grained caviar, which may be put in any white tin or wooden, or better in glass or porcelain, container, and tightly covered. This caviar may be kept only in a cool room, ice-box, ice cellar, refrigerating room, etc. The best temperature is from +8° to +5° C. (46.5° to 41° F.). When taken from the cool room, it must be used promptly and therefore it is advisable to pack the fresh caviar in small containers, not larger than 4 to 5 pounds, better, one-quarter, one-half and one-pound. No pasteurization is admissible for such a tender and delicious product as this real fresh Russian caviar.

Pickled grainy caviar, prepared for export, is salted to a greater extent, and is manufactured in some other way. No dry salt is used here, but a saturated pickle, which is poured in the tub with the roe and passed through a large meshed sieve as explained above. The roe is kept in this strong pickle several minutes, until the grains of roe become rather rough, on being felt by the fingers, and make a slight noise like small pieces of grain rubbing against one another. In order to finish the operation at the right moment, without oversalting the caviar, the operator must have a good experience. The eggs are swimming in the pickle and they are taken out by sieves, on which the caviar remains while draining until it becomes dry. Then the caviar is poured from the sieves directly into the containers, which, as a rule, are round, low tin cans. This caviar has a more salty taste in comparison with the fresh caviar, but it looks much better as every grain is separate, and it may be kept without damage for a longer period. Air-tight covers on the tin cans, with rubber bands inside, are used as a rule for export caviar. The method of preparing pressed caviar is the same from the beginning until the moment of taking the salted eggs from the tub. The eggs are kept in the pickle a little bit longer in order to get them hard, which, however, are not so hard that they can not be crushed by the fingers. Taken from the tub by sieves, the salted caviar is put in a sort of mat—or cheese-cloth sacks—and is then put under the press. When being pressed, the liquid, as a milk in appearance, is poured from the sacks, and the contents of the sacks become a sort of soft cheese or cake made from caviar. It has the same delicious taste and flavor as regular caviar. It may be sliced with a knife. The pressed caviar may be preserved in wooden barrels for a long time, in ice cellars or, better, in cold stores, with a temperature of +8° C. (46.5° F.). In order to avoid drying, the caviar is covered with oiled paper and sealed perfectly tight.

Dried Mullet Roes.

Dried mullet roes are prepared to a limited extent along the southeastern coast of the United States from North Carolina to Florida. The unbroken roe bags containing the mullet roe are placed in tubs and either sprinkled with salt, or brine is poured over them. About 5 quarts of salt are added to each 100 pounds of eggs. If too much salt is added it causes the egg sacks to break. After the roes have remained in the salt or brine for 10 to 12 hours they are drained and spread on boards in the sun until they become dry. They are taken in each night to prevent their becoming wet by dew. During fair weather the drying process requires about a



Courtesy Philippine Bureau of Science.

Fig. 153.—Philippine shark's fins.

Top to bottom.

Left	Right
Large white-spotted fin (*boon leong sit*).	Large white fin (*chu sit*).
Small white fin (*peh sit*).	Small white fin (*khiam sit*).
Large black fin (*tua sit*).	Small black-tipped fin (*oh ku sit*).
Fin prepared for cooking.	Small black fin (*seow oh sit*).

week. The finished product varies in color from a yellowish brown to a dark red.

Shark Products.

Shark-Flesh Paste.

Shark and dogfish are highly prized as articles of food in the Orient. The Japanese prepare an especially tasty dish from shark and dogfish flesh called shark-flesh paste. The flesh is freed from skin and bones and cut into shreds which are pounded in a wooden or stone mortar with a wooden pestle until they are reduced to paste. During the pounding a little salt and various other condiments are added; this practice varies in different parts of the islands. The paste is made into rolls upon a board much as butter or cream cheese is handled. The rolls are steamed over boiling water for 20 minutes in a closed oven. The product is white and has an attractive appearance; it will keep for several days even in summer.

Preservation of Shark Fins.

Shark fins are largely used for food by the Orientals, particularly the Chinese; their chief use is for the making of soup. Shark fins are classed as either white fins or black fins, although none of the fins are perfectly black or perfectly white. They are divided into several groups of different values depending upon the color, size, and variety. The chief commercial classes of fins are the following: white spotted fin (Chinese *boon leong sit*) graded into large and small white fins, large white fin (*chu sit*), small white fin (*peh sit* and *khiam sit*), large black fin (*tua sit*), small black fin (*oh sit* and *seow oh sit*), small black-tipped fin (*oh ku sit*). The more important shark fins are shown in Fig. 153 on page 412.

In preparing the fins for market they are merely cut from the shark; the cut portion is well salted or dusted with lime, and dried in the sun.

Japanese Canned Fish Pudding.

The Japanese prepare an unusual product called canned fish pudding by grinding and kneading the fish meat, which is seasoned with salt, sugar and *mivin,* a liquor similar to vermouth. The pudding is placed on a wooden board and boiled or steamed; after which it is slightly baked before it is packed in the cans and sterilized.

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Chapter 21.

Fishery By-Products. Fish Oils.

Importance and Location of the Industry.

Whale and porpoises have been hunted for their blubber since early times. The oil rendered from the blubber was formerly used in lamps for illumination. But only recently has the value of the various fish oils been recognized. The ever increasing use of paints and varnishes has created a great demand for linseed and other paint oils. The production of flaxseed has been unable to keep pace with this demand. Other oils have been brought into use; menhaden and tung oils are two of the most popular substitutes for linseed oil. Within the past ten years, the deodorization and hardening of fatty oils by hydrogenation have been perfected to such an extent that hard, colorless, odorless fats are manufactured from fish oils. The hydrogenation and soap making industries now use nearly the entire output of menhaden oil.

The chief centers of the fish oil industry are: the northern ports of the east and west coasts of Great Britain; Massachusetts, Connecticut, New York, New Jersey, Delaware, Virginia, North Carolina, Florida, California, Washington, and Alaska in the United States; and in Japan. In 1919, Japan produced fish oil valued at over $6,500,000.

The statistics relative to the production of fish oils in the United States for the year 1922 are presented in Tables 49 and 50.

General Characteristics.

Fish oils are liquid fats and consist chiefly of various proportions of the glycerides of saturated and unsaturated fatty acids. Vegetable and animal oils may be divided into three general classes, viz.: non-drying, semi-drying and drying according to their ability to absorb oxygen from the air and thus be converted into solid insoluble compounds. Fish oils belong to the two latter classes. Menhaden, sardine, salmon, herring, bonito, albacore, mackerel, stickleback, akajei, anchovy, and whiting oils are classed as drying oils and may be used for the manufacture of paints and varnishes. Whereas dab, sprat, hoi and carp oils have relatively low iodine values and must be classed as semi-drying oils: they cannot be used in paints and varnishes, since upon drying they do not absorb sufficient oxygen from the air to form hard non-tacky films.

Fish oils are obtained from all parts of fish, whereas the fish-liver oils are prepared from the livers only. The bodies of the liver-oil yielding fish such as the cod are, as a rule, very lean and yield very little oil; whereas the livers of fatty fish usually contain little oil. Fish oils differ

TABLE 49

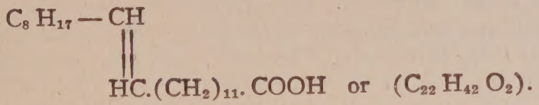
Fish Oils Other than Menhaden Produced in the United States in 1922

Products	Massachusetts and Maine		Maryland		New York, Virginia, North Carolina, and Florida		Washington, Oregon, California, and Alaska		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Oil—										
Salmon, gallons	.....	.....	.....	.....	.....	.....	25,989	$ 9,435	25,989	$ 9,435
Sardine, "	.....	.....	.....	.....	.....	.....	428,859	145,668	428,859	145,668
Tuna, "	.....	.....	.....	.....	.....	.....	86,099	62,702	86,099	62,702
Herring, "	25,121	$5,726	.....	.....	.....	.....	425,241	144,418	450,362	150,144
Whale, "	.....	.....	.....	.....	.....	.....	1,863,015	731,000	1,863,015	731,000
Sperm, "	152,986	81,082	.....	.....	.....	.....	231,144	76,632	384,130	153,714
Liver, "	67,459	31,774	.....	.....	.....	.....	.....	.....	37,559	18,319
Cod liver, "	3,980	1,792	.....	.....	.....	.....	100	100	4,080	1,892
Miscellaneous, "	99	1,150	3,500	$595	11,877	$3,469	107,327	34,384	122,803	39,598

in chemical composition from liver oils chiefly in that the latter contain relatively high amounts of an unsaponifiable substance called cholesterol.

The exact nature of the fatty acids in fish oils is still imperfectly known. Most of the oils deposit small amounts of "stearine" upon standing in the cold for long periods. Fish oil stearine usually consists of a mixture of the glycerides of stearic and palmitic acids. Twitchell (see page 429) found that the fatty acids obtained upon the hydrolysis of menhaden oil contained 22.7 per cent of palmitic acid and 1.8 per cent of stearic acid, the glycerides of which are solid fats. The fish oils listed above as drying oils contain relatively high proportions of the glycerides of the highly unsaturated fatty acids, whereas the semi-drying oils contain lesser amounts of these glycerides.

Bull[1] states that all marine animal oils contain erucic acid



$$\begin{array}{l} C_8H_{17}-CH \\ \qquad\quad \| \\ \qquad\quad HC.(CH_2)_{11}.COOH \quad \text{or} \quad (C_{22}H_{42}O_2). \end{array}$$

and an unsaturated fatty acid of the formula $C_{20}H_{38}O_2$. Tsujimoto[2] has shown that a large number of fish, liver and blubber oils contain from 6 to 9 per cent of the glycerides of clupanodonic acid $C_{18}H_{28}O_2$. The free fatty acid is a pale yellow liquid having a fishy smell. Many observers have attributed the characteristic odor of fish oils to the presence of this acid. It has been shown that upon slight hydrogenation of the oils the fishy odor is practically destroyed. Since this is one of the most highly unsaturated acids in fish oil, it is one of the first to combine with hydrogen upon such treatment.

Owing to the presence of clupanodonic acid, the *bromide test* may be used for the detection of fish, liver and blubber oils. Hehner and Mitchell[3] suggested the test for the purpose of differentiating between drying and semi-drying oils. The test as modified by Lewkowitsch[4] is given below:

> Dissolve 1 to 2 grams of oil in 40 c.c. of ether to which a few c.c. of glacial acetic acid have been added, cool the solution in a corked flask to 5° C., and add bromine from a finely drawn-out pipette, drop by drop, until the brown coloration remains permanent. (If the temperature were allowed to rise, evolution of hydrobromic acid would become noticeable. In that case the experiment must be rejected.) After standing for 3 hours at a temperature of 50° C., the liquid is filtered through a plaited filter, and the precipitate washed 4 times in succession, using each time 10 c.c. of chilled ether. The residue is finally dried in a water oven to constant weight.

Clupanodonic acid forms octobromo stearic acid ($C_{18}H_{38}O_2Br_8$) upon bromination. This substance contains 69.87% of bromine, blackens at 200° C. and decomposes upon further heating. This property of decomposing before melting may be used as a qualitative test to distinguish

[1] *Chem. Zeit.*, *23* (1899), 996.

[2] *Chem. Rev. Fett. Harz-Ind.*, *20* (1913), 70-73.

[3] *Analyst*, *23* (1898), 310-318.

[4] Chemical Technology and Analysis of Oils, Fats and Waxes, *1* (6th Ed.), 485, 581. London, 1921.

between this bromide and linolenic hexabromide, as the latter melts at 180-181° C. Linolenic hexabromide is the ether insoluble bromide obtained upon the bromination of the fatty acids from linseed oil. Thus deodorized fish oil may be distinguished from linseed oil and other vegetable drying oils. The ether insoluble bromo-derivatives consist either of octobromide or of hexabromide or a mixture of both. Since clupanodonic octobromide contains 69.87 per cent and the hexabromides about 63.32 per cent of bromine, the respective amounts of acids can be calculated from the following two equations:

$$x + y = 100$$

$$\frac{69.87\,x}{100} + \frac{63.32\,y}{100} = B$$

in which x is the percentage of octobromide, y the percentage of hexabromide and B the percentage of bromine in the ether insoluble bromides.

Since fish, fish liver, seal, whale, and sperm oils are the only oils known to contain large amounts of the glycerides of clupanodonic or other highly unsaturated acids capable of forming octobromides, this test may be used to distinguish between marine animal oils and the drying vegetable oils.

Fish oils when treated with nitrous acid, as in the elaidin test,[5] yield either a pasty or buttery mass, separating from the fluid portion, or merely a liquid product. Non-drying oils yield solid hard masses when treated with nitrous acid.

Old marine animal oils and those bleached by sunlight yield dark brown soaps upon hydrolysis with alkalies, whereas the freshly prepared oils give slightly colored soaps.

Menhaden.[6]

The Industry.

The manufacture of menhaden oil and scrap is an American industry of considerable importance. It is located along the eastern coast from Massachusetts to Texas. This fish is not caught elsewhere in large quantities. In former years, menhaden factories operated as far north as Maine, but, in recent years, fish have not been caught in sufficient quantities to warrant their operation. In 1922, however, an unusual number was caught along the Maine Coast. The first steam factory was established in Rhode Island; others were erected in New York, Connecticut and Maine before the industry was established in Virginia, its present center. The steamer *Ranger* of Greenport, N. Y., was sent to Virginia in 1866. This vessel was equipped with cooking and extraction apparatus, and was the first floating factory. The first Virginian factories were built in 1868; one was on Tanners Creek and the other on Back River. The following year the first factory was constructed at Reedville, Virginia, which is now the most important scrap oil center on the coast. The first menhaden factory in North Carolina was built on Harkers Island in 1865.

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[5] See Archbutt, *J. Soc. Chem. Ind.*, *5* (1886), 304.

[6] The writer wishes to acknowledge his indebtedness to Mr. R. L. Greer, U. S. Bureau of Fisheries, for much of the information relative to the menhaden industry.

The annual catch of this fishery varies greatly; the quantity of oil produced is even more variable as the fish are fatter some years than others. The average annual catch is about a billion fish. In *1921,* 1,031,540,831 menhaden weighing 618,924,499 pounds were caught. From this quantity of fish the following products were prepared: Dry scrap and fish meal—37,858 tons valued at $1,380,455; acidulated scrap—44,454 tons valued at $895,140; crude scrap—350 tons valued at $10,500; and 6,260,478 gallons of oil valued at $1,719,892; the total value of the products being $4,005,987. The complete statistics of the industry for 1922 are given in Table 50.

As the menhaden is a migratory fish, the season differs on various parts of the coast. Some are found in Florida throughout the year, but the bulk of the catch is taken from April 1 to November 1. The menhaden caught in Florida are captured chiefly within 15 miles of the mouth of the St. Johns River. At other points along the coast, the spring and fall "runs" determine the season. In North Carolina, the northward movement of the fish generally ends about the middle of June. Little fishing is done from that time until late September or early October when the fish return. In the Chesapeake Bay region, the steamers fish chiefly at sea from the beginning of the season, late in May, until the first of July. During July, August and September the fishing is chiefly in the Bay from which about 15 per cent of the entire catch is taken. During October and until the end of the season, about the middle of November, the Virginia steamers fish outside again. The season and fishing grounds for the Delaware and New Jersey steamers is practically the same as that given for those from Virginia except that they are excluded from the Chesapeake Bay. The New York and Connecticut fishermen have a shorter season. They seldom go farther south than the Virginia capes or farther north than Boston Bay.

Steamers and motor boats have gradually supplanted the schooners and sloops formerly used in the fishery. The modern steamers have the appearance of large tugs with high bows. The quarters are forward, the engine boilers and bunkers toward the stern, leaving the hold in the middle of the boat where the deck is low so as to facilitate the handling of the fish. Figure 93 on page 244 shows a modern menhaden steamer on the fishing grounds.

Menhaden are captured chiefly in purse seines. Greer[7] has described in detail the fishing methods commonly employed:

> As soon as the fishing grounds are reached the captain and the mate repair to the "crow's nest" at the mast, from which point of vantage they survey the surrounding waters to locate the fish, an experienced eye readily distinguishing the reddish hue which indicates their presence. When a school is sighted, those aloft rapidly descend and prepare to "lower away" the seine boats; the striker drops off in advance and rows toward the fish to keep trace of them and indicate to the captain, by signals made with an oar, the direction in which they are moving. The

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[7] *Bureau Fisheries, Rept.* 1914, Appendix 3; also Doc. 811. Reprinted with additions, 1917.

captain is in charge of one of the boats and the mate directs the movements of the other.

At the opportune time the seine, one-half of which is stowed in each boat, is thrown out by the "seine setters," the oarsmen rapidly rowing in a circular direction in order that they may surround the fish; the striker in the meantime has taken a position on the opposite side of the school, and by splashing the water with an oar endeavors to prevent their escape. When the two boats meet a large hook attached to a line made fast to the bow of the mate's boat is caught under the center thwart of the captain's boat to prevent them drifting apart. The tom is then dropped overboard and the men begin hauling both ends of the purse line through two snatch blocks which are attached to an upright iron support about 18 inches high called the "crane" and which is fitted in the port gunwale of the captain's boat about 10 feet from the bow; the line is carried directly across to two snatch blocks hung to the starboard gunwale, the one end continuing on toward the stern and through another block attached to the same gunwale and the other end going to the men in the mate's boat. The ends of the net are hauled into the boats as it is being pursed and arranged in an orderly manner so as to be in readiness for the next set; when the rings are all in, the tom line is placed in one of the blocks on the crane and the tom hauled aboard. The hook referred to above as holding the boats together is then released and the bows are lashed together.

TABLE

Products of the Menhaden

Products	Massachusetts, Connecticut, New York		New Jersey and Delaware	
	Quantity	Value	Quantity	Value
Fish Utilized—				
Menhaden No.	258,086,285	$515,344	169,504,000	$358,994
Mfg. Products, Tons—				
Dry scrap and fish meal	18,024	530,606	690	30,548
Acidulated scrap	......	......	15,097	311,632
Crude or green scrap	43	344	......	......
Total	18,067	530,950	15,787	342,170
Oil (gallons)	2,066,461	904,252	916,570	416,169
Grand Total		1,435,202		758,339

[a] 747,470,402 pounds.

It is sometimes necessary for the striker to tend the cork line to guard against its being submerged when the fish are all in the bunt of the net. When all is in readiness the captain signals to the pilot to bring the steamer alongside for the purpose of transferring the fish to the vessel hold. The hanks, which hang along the gunwale, are made fast to the beckets on the bunt of the seine so as to hold it close to the vessel, and the bailing begins. The bailing net is simply a bag 4 feet deep, made of cotton twine and hung to a circular frame about 4 feet in diameter, made of 1-inch iron; it has a wooden handle approximately 12 feet long. The net is suspended from a boom hung to the mast directly over the hold and so arranged as to swing back and forth; it is raised by a small engine placed on the deck a little aft of amidships. The fish are dumped by means of a line attached to the bottom of the net and passing through a block hung to the boom above. Two other lines attached to the rim of the net, one held by a man standing on the deck of the steamer and the other by a man in one of the seine boats, are designed to assist in guiding the net as it is raised and lowered. The handle is controlled by a man standing on the deck along the gunwale.

It is possible to handle fish at the rate of a half million an hour with this net. When a set is made and the seine found to be empty when pursed it is said to be a "stab"; when they begin paying out the net and the fish are seen to disappear before it is all out, it is a "pull-back." The usual time required for making a set and pursing the seine is 30 to 40 minutes.

No fishing is done at night; the steamers always make some harbor, preferably their home port, but if too far from that they run in to some place more convenient.

Methods of Manufacture.

Unloading.—Formerly menhaden were unloaded by means of tubs, each having a capacity of 500 fish, which were filled by hand and raised by means of a block and tackle. The fish were dumped into bins or small cars which conveyed them to the factory. All the larger and best equipped factories now use bucket elevators, similar to those used for handling grain, for removing the fish from the vessels. The elevator is so arranged that it may be lowered into the hold of the vessel where the fish are fed to it by four or more men. The elevator empties the fish into a measuring or weighing device. The fish are then dumped into a conveyor which carries them either directly to the cooker, or to the "raw box" or bin in which they are stored until they can be cooked. These bins are usually about 10 feet deep but their length and breadth vary according to the capacity of the plant and the number and size of cookers employed. The floor slants towards the middle where a conveyor is placed in a close box with a cover which may be removed in sections when the bin is to be emptied.

50

Industry in 1922

Virginia		North Carolina		Georgia, Florida, and Texas		Total	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
460,612,000	$ 947,995	188,162,430	$376,320	136,085,954	$259,037	[a] 1,212,450,669	$2,457,690
34,244	1,526,864	8,783	320,817	6,080	256,616	[b] 67,821	2,665,441
......	......	6,615	160,341	4,000	84,000	25,712	555,973
......	......	......	......	......	......	43	344
34,244	1,526,864	15,398	481,158	10,080	340,616	93,576	3,221,758
2,560,065	958,831	967,696	396,055	501,885	229,526	7,102,677	2,904,833
	2,485,695		877,213		570,142		6,126,591

[b] Of this quantity 7,172 tons valued at 390,677 were reported sold as fish meal.

Cooking.—Since it is desirable to cook the fish as soon after they are taken from the water as possible, the cooking is usually begun as soon as the unloading is commenced. Stale fish putrefy quickly and are much more difficult to handle in that condition. Cooking breaks the fat cells so that the oil is easily obtained when the fish are pressed.

Formerly this process was carried out in open vats, but all modern reduction plants now employ continuous steam cookers which operate automatically and require no labor for filling or discharging. The open vat style of cooker consists of a false-bottomed tank beneath which are placed perforated steam pipes. The vats are partially filled with water which is heated with steam. Sufficient fish are then added to nearly fill the tanks; the steam is turned on and the fish cooked for about 20 minutes.

The continuous fish cooker, in general use to-day, consists essentially of a stationary horizontal steel plate cylinder from 16 to 30 inches in diameter and from 20 to 40 feet in length fitted with an intake hopper at one end and a special discharge opening at the other end. The lower portion of the cylinder is usually provided with several longitudinal rows of steam inlets or nozzles so placed that jets of live steam can be forced directly into the mass of fish moving slowly over the inner surface of the cooker shell. A hollow shaft, rotated by means of suitable gearing and supported in the two heads of the cooker, extends through the longitudinal centerline of the cylinder. Frequently, this hollow central shaft is also provided with a series of steam nozzles, between the turns of the conveying screw and connected to a steam supply through stuffing boxes at its ends, which permits the injection of live steam directly into the upper part of the moving fish mass.

This type of cooker has a smaller shell about 8 feet long and 1 foot in diameter attached to the discharge end, a little lower than the main cylinder, and either at right angles or parallel to the same. This is designed to keep the steam from escaping. The mass of cooked fish drops into the smaller cylinder after passing through the cooker and is carried through by a screw conveyor.

This type of cooking machine receives its supply of material by means of a mechanical conveyor directly from the raw fish bin and delivers the product in a homogeneous and thoroughly digested condition, containing on the average from 75 to 80 per cent of water.

Pressing.

Curb and Hydraulic Presses.—In the early days of the industry, curbs and hydraulic presses were exclusively used for pressing the oil and water from the fish. And, even to-day, some operators prefer them to the continuous screw presses, because the screw press exerts such a great pressure that quantities of fleshy matter are forced out with the oil and water, thus rendering the separation of these in the oil room more difficult. If the fish are partially decomposed, a considerable loss of scrap is incurred if they are pressed in a continuous press.

When the old-style curbs and hydraulic presses are used, the mass of fish drops from the cooker to a screw conveyor leading to a bucket conveyor to be carried to the second floor, where it passes to a second screw conveyor by which it is emptied into the draining tanks. Here it remains over night; much oil and water drains off and is carried through troughs to the oil tanks.

In the morning the cooked mass is pitched out of the tanks into the curbs by hand using large forks. The common form of curb is a cylindrical tub mounted on a truck with wheels about 20 inches in diameter, so as to run on a track built alongside the draining tanks. The usual depth of the tub is 40 inches; its diameter is about 35 inches at the top, and slightly wider at the bottom; it is constructed of about 100 beveled iron staves, each three-eighths inch thick, seven-eighths inch wide on the outer side, and slightly wider on the inner side, with sufficient space left between the staves to permit the drainage of the oil and water. A hollow core, about 12 inches in diameter and 33 inches long, fits in the center of the curb; this is made of staves similar to those already described, and has a rounded top of iron in the center of which is an eyebolt. The bottom of the curb is simply a piece of heavy sheet iron attached to the lower band of the curb by means of a loose-pin hinge; the opposite side of the bottom is held in place by a latch which is opened by a lever when the curb is to be emptied, permitting the bottom to swing.

The filled trucks are run under a stationary head which fits closely inside the curb. A powerful hydraulic press raises the curb, thus pressing the fish against the head and forcing out most of the remaining oil and water. Shields of sheet iron, or other material around the curb, prevent the oil and water from squirting around the room when the pressure is applied, and as the liquid is forced out, it runs through troughs to the oil room. When the pressure is relaxed, the curb slowly descends to its former position on the rails and is pushed from beneath the head. The core is held by means of a hook attached either to a chain working in a pulley suspended from above, or to a piece of wood laid across the top of the curb, while the bottom is released by a lever and the pressed mass of fish drops through an opening in the floor to the room below. Another form of curb, which is used in some plants, has latches in the iron bands, thus permitting the release of the hard cake at the side.

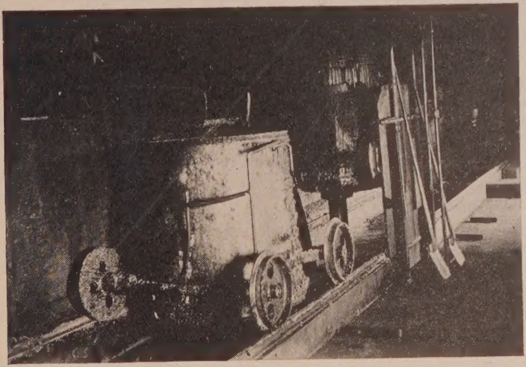


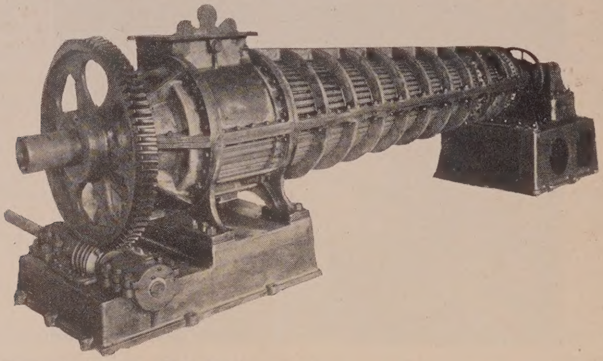
FIG. 154.—Curb used in the hydraulic pressing of oil and water from menhaden scrap.

Continuous Screw Presses.—If screw presses are used, the digested fish are conveyed directly from the cooker to the press, thus eliminating the draining tanks and the labor involved in pitching the fish into the curbs. Moreover, the fish is not permitted to cool and is kept hot by steam jets during the pressing.

A common form of continuous press is composed of a horizontal heavy cast steel frustro-conical curb frame, having a suitable intake hopper at one end and provided on the interior with a large number of tapered and beveled edge, longitudinal steel slats, spaced about 1/32 inch apart. A closely fitted pressing screw, conforming to the interior slatted surface and mounted on a large hollow steel shaft, is rotated very slowly, through heavy gearing, within the slatted drainage casing.

The hollow shaft is provided with a great number of small steam nozzles, between the convolutions of the pressing helix, and fitted with a suitable stuffing box at each end for connecting up with a high pressure steam supply. This arrangement permits of forcing jets of live steam directly into the cooked mass while under heavy pressure in the machine, serving to prevent clogging and likewise to maintain the material at high temperature during the pressing operation which is essential for maximum oil extraction.

The discharge end of the machine is fitted with a special adjustable pressure regulating device by which the rate of discharge and the size of the outlet can be varied to suit the character and condition of the material being handled without stopping the press and without interfering with its operation. This feature is of great importance since the oil content of the fish and their age before processing determines largely the method of handling for the best results.



Courtesy American Process Co.

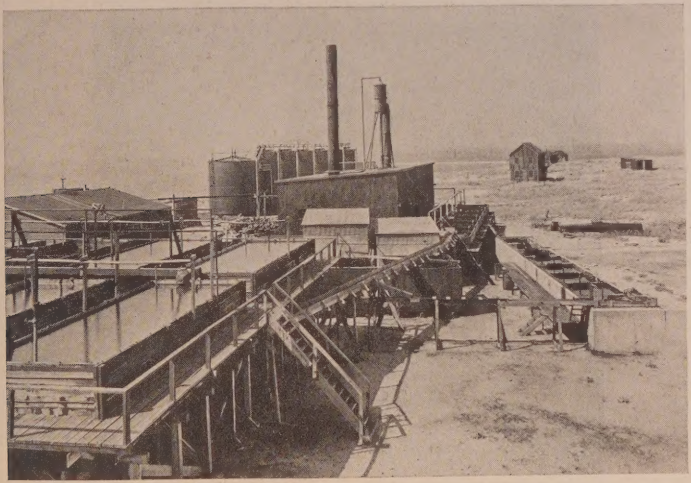
Fig. 155.—Automatic screw press for menhaden scrap.

The cooked fish pulp enters the press directly from the cooker in a continuous stream and a thoroughly pressed and matted mass, called pressed scrap, is discharged continuously at the opposite end. The intense pressure to which the material is subjected, during its passage through the machine, results in an expulsion of most of the water and oil from the mass through the drainage openings in the slatted casting of the press curb.

One form of screw press, 18 feet long, has a capacity of 80,000 to 100,000 fish per hour when driven by a 50 H. P. engine. Smaller presses 12 feet long usually have a capacity of about 40,000 fish per hour and may be operated with a 35 H. P. engine.

Separation of the Oil and Water.—The oil and water flowing from the press are conducted through a trough to the receiving tank, where a considerable quantity of the solid matter forced through the press with the liquid settles and is drawn off through an opening in the bottom of the tank. From the receiving tank, the liquid passes through a series of separating tanks in which the separation of oil and water gradually takes place. The oil may flow directly over the edge of one tank into the next, or into a trough built on the inside of one tank along the side next to the one to receive the oil; the latter arrangement is sometimes called a "self-skimmer."

Sufficient steam is applied through pipes placed under false bottoms to keep the liquid in the tanks at a temperature 52 to 65° C. The water is withdrawn from the receiving and separating tanks by means of a "coffee pot" or siphon box 6 by 12 inches in size, built against the inside of the tanks, with the lower end opening about 6 inches from the bottom of the tank. The oil passing from the last of the series of settling tanks is practically free from water and is then run into the cooking tanks, where it is heated to 100° C. The "cooking" requires from 20 to 30 minutes.



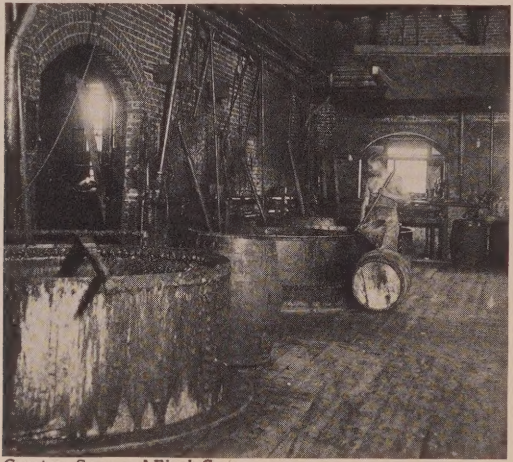
Courtesy Swan and Finch Co.

FIG. 156.—Tanks for the separation of menhaden oil from water.

After the heating the oil usually is run into storage tanks, which are usually made of metal and are without covers, so that the oil is bleached and washed by the sun and rain.

Gurry.—The sediment collecting in the bottom of the tanks during the separating and cooking process consists of fine particles of flesh containing considerable quantities of oil and water and is called gurry. This is sprinkled with dilute sulphuric acid to facilitate the separation of the oil, and is then cooked by steam for 20 to 30 minutes in the same manner as the bulk of the oil, and while hot, it is pressed.

Two types of presses are in common use, viz. the bay oil press and the filter press. The bay press is much cheaper and is somewhat simpler to operate and therefore is in more general use. This type of press is also used for the separation of cod-liver oil. It consists of an iron framework about 10 feet high, forming "bays" each 28 inches wide, in which are a number of steel plates. The gurry is put into canvas bags which are then folded in such a manner as to prevent the gurry from running out. Two bags are placed on each plate, with a total of 100 to 125 to each bay. The pressure is applied by a lever attached to a pinion working in an upright rack, the lower end of which fits in the head of the press. Weights are hung on the ends of the levers to obtain the necessary pressure.

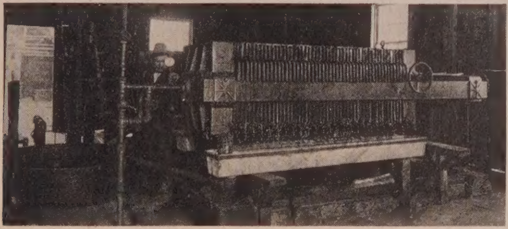


Courtesy Swan and Finch Co.

FIG. 157.—Tanks for the heating of menhaden oil.

The other type of press used for gurry is the recessed plate filter press. The common size for gurry has plates 30 inches square recessed about an inch on both sides, having a hole 3 inches in diameter in the center. A sheet of heavy canvas with holes cut to fit the hole in the plate is thrown over each plate and fastened into place by grommets. From each side of these plates projecting lugs rest on a pair of parallel bars which are fitted in the frame at each end. The gurry is pumped in through a channel 3 inches in diameter formed by the holes in the center of the plates, from which it passes to all parts of the press. The pressure forces the liquid through the canvas into the grooves in the plate; it then runs down the plate to outlet cocks to the trough leading to the oil tank. To prevent the cloths being clogged quickly, either infusorial earth or sawdust is mixed with the gurry before filtration. The solid matter retained on the surface of the canvas gradually fills the chambers and slows down the filtration. When the solid cake nearly fills the chambers, the press is opened, the cake removed and placed with the rest of the scrap. A filter press with 50 plates 30 inches square has a capacity of 60 barrels of gurry each 24 hours.

The oil runs from the gurry press into a tank, from which it is pumped to the oil room where it is washed with water, and, if it is found to be sour, it is heated with steam again. Gurry oil is of darker color and is inferior in quality to the other oil, yet it is usually mixed with the better quality oil as the quantity obtained is so small in comparison with the total bulk of oil.



Courtesy Swan and Finch Co.

FIG. 158.—Filter press for gurry.

Some factories do not bother with the gurry but discard it along with the water from the oil tanks. But, since it sometimes contains as much as 30 per cent of oil and an equal amount of scrap, it is worth while to press any considerable quantity of it.

Yield of Oil.

The yield of oil varies considerably from year to year, and at different seasons, and on different parts of the coast. Some years, fish are fatter than others, and they are always larger and fatter during the fall than at any other season. As a rule, the menhaden taken from northern waters produce more oil than those taken from southern waters. The northern factories sometimes get as much as 20 gallons of oil from each 1000 fish. The maximum yield for the Middle Atlantic States is about 15 gallons per 1000 fish. Those caught in the Florida waters rarely yield more than 8 gallons and in the early spring the yield is often less than a gallon of oil per 1000 fish. The average number of gallons of oil per 1000 fish during the season of 1912 was as follows: Connecticut 11.73; New York 11.36; New Jersey 5.08; Delaware 7.72; Virginia 3.72, and North Carolina 1.98.

The quantity and quality of oil produced also depends upon the manner in which the oil is handled during the process of separating and cooking.

Grades of Oil.

The quality of oil prepared from fat fish is superior to that from lean ones. Fish caught by the Virginia fishermen in the sea produce oil of a much superior quality to that made from the fish caught in the Chesapeake Bay.

Four grades of crude menhaden oil are recognized, viz.: *A* light amber, *B* amber, *C* light brown, and *D* dark brown. The color of the crude oil depends to a large extent upon the condition of the fish when cooked. When fresh they usually produce a clear, "sweet" oil; if they have putrefied the oil is dark, and if the decomposition has proceeded far enough, the odor of the oil produced is that of decayed fish.

Refining.

The principal markets for crude menhaden oil are Cincinnati, New York, New Bedford, Baltimore and Boston, where it is usually refined, bleached and winter pressed. The various grades of refined oil are the following: "Extra bleached winter fish oil"; "bleached winter fish oil"; "light winter-pressed fish oil" and "brown winter-pressed fish oil."

In refining the oil is allowed to stand for a considerable length of time in the cold, usually in outdoor tanks in winter. During this period "stearine" separates. The oil is filtered over fuller's earth or other decolorizing agent while cold, producing "bleached winter oil."

Many processes for deodorizing fish oil have been patented. The principal processes are listed below:

Eng. 7901; 1906; E. Böhm. Heating in vacuo to 350–400° C.
Eng. 23,534; 1906; Bottaro. Odorless fatty acids obtained from fish oil by saponification with lime and subsequent decomposition of the lime soap with sulphur dioxide gas.
Eng. 135,295 (1919); Calvert. Heats fish oil in atmosphere of inert gas to temperature of 250–300° C.
Fr. 448,517 (1913); S. H. Goldschmidt and C. Jorgensen. By treating the "sebacic acid" of fish oils with sodium hypochlorite containing as little sodium hydrate as possible.
Eng. 12,525 (1905); Ger. 169,410 (1905). A. de Hemptinne. Treatment of fish oils with ozone.
Fr. 394,530 (1907); G. van der Heyden. Treating the fish oils with 6 to 8 times the volume of alcohol at 70°, washing with hot water and treating the washed oil with fuller's earth at 75°–80° C.
Fr. 394,456 (1909); C. H. J. Welfling. The fish oil is emulsified with alcohol and after separating the alcohol the oil is washed with hot water to remove the alcohol retained by the oil. The washed oil then is treated with fuller's earth or animal charcoal.
Ger. 202,576 (1907); E. Petersen and G. H. Holstein. Treatment with superheated steam, chalk and charcoal.
U. S. 823,361 (1906); Potolowsky. Concentrated sulphuric and nitric acids.
Ger. 162,638 (1905); Sandberg. Concentrated sulphuric acid.
U. S. 1,260,072 (1918); Eng. 120,820 (1917). Schuck. Fish oil is heated to temperatures ranging up to 300° C. in atmosphere of hydrogen or inert gas.
Eng. 18,925 (1913); G. Weiss. The oil is heated to 250°–300° for several hours.
Ger. 294,163 (1913); G. Weiss. The oil is heated to 200° C. under atmospheric pressure and subsequently treated with steam in the presence of basic substances, especially oxides or hydroxides of alkali, alkaline earth or other metals.

Gardner[8] suggests the addition of substances having a pronounced but more agreeable odor. Five to ten per cent of pine oil may be used and produces a rather pleasant turpentine odor.

Composition.

The maximum and minimum constants for menhaden oil that have been published are given below:

Menhaden Oil.

Specific gravity at 15° C.	0.9284–0.9311
Solidifying point °C.	−4
Saponification value (mgs. KOH)	188.7–193.0
Reichert value (c.c. $\frac{N}{10}$ KOH)	1.1
Iodine value (per cent)	147.9–192.9
Maumené test °C.	123–128
Specific temperature reaction	306
Butyro-refractometer 40°	71.3–72.0°
Unsaponifiable matter (per cent)	0.61–1.60

The high saponification value, the small amount of unsaponifiable matter, and the high proportion of glycerol yielded upon saponification, show that menhaden oil consists almost entirely of glycerides. Twitchell,[9] who studied the composition of the fatty acids of menhaden oil by his process of observing the lowering of the melting point by the addition of pure fatty acids, gives the following composition:

	Per cent
Palmitic acid	22.7
Myristic acid	9.2
Stearic acid	1.8
Unsaturated acids with 16 carbon atoms	none
" " " 18 " "	24.9
" " " 20 " "	22.2
" " " 22 " "	20.2

The unsaponifiable matter consists chiefly of cholesterol, which causes the slight optical activity of this oil.

Uses.

Much menhaden oil is hydrogenated and used for the manufacture of soaps. When properly hydrogenated, a solid, odorless, almost colorless fat is produced. This hardened oil is extensively used in the manufacture of laundry soap and the cheaper grades of toilet soap. Some is also used for the preparation of certain lard substitutes. In Europe, menhaden and other fish oils and whale oils are hydrogenated and either used in the

[8] *Paint Mfrs. Assoc., Educational Bureau Circular, 68* (1919).

[9] *J. Ind. Eng. Chem., 9* (1917), 581-4.

manufacture of candles, soap, leather dressing, etc., or marketed under trade names such as talgol, talgit, candelite, candelite extra, and olinit. The iodine numbers of such hardened oils vary from about 8 to 70, depending upon the quality, the lower the iodine value the higher the quality.

Menhaden oil is also used in the manufacture of paints, varnishes and stains. For this purpose winter oil must be used as stearic acid forms insoluble compounds with the substances commonly used as driers. These insoluble compounds slowly precipitate out from the varnish or paint on standing and cause flecks in the film. Menhaden oil is especially valuable in the preparation of certain heat resisting paints. For roof and barn paints and coatings for structural steel, menhaden oil is excellent as the dried film is not as brittle as that formed by linseed oil and it is somewhat less affected by sudden changes of temperature. Heat treated oil containing driers must be used as the raw oil film is somewhat tacky even when completely dry. In white paints rather large amounts of driers are required in order to cause the oil to dry to a permanently hard film and thus prevent the darkening caused by dust adhering to the tacky film.

Formerly, its principal use was in the currying trade and in the manufacture of degras and sod oil; large quantities are still employed by leather manufacturers. Some is used in the manufacture of linoleum and for making rubber substitutes and water proofing compositions.

Sardine and Herring Oil.

The Industry.

Sardine oil is prepared chiefly from the heads, tails and entrails of sardines used for canning. True sardines are canned in large quantities in California, in France, Spain and Portugal and it is from these coasts that sardine oil comes. Japanese sardine oil is derived from a somewhat different species, *Clupanodon melanosticta,* but it often contains other oils and therefore is variable in composition.

In 1921, California produced 170,977 gallons of sardine oil valued at $35,760. Much sardine waste was mixed with other fish wastes and converted into oil, feed, and fertilizer; the oil produced therefrom was sold as "fish oil," and listed in the statistics as miscellaneous fish oils. The figures for 1922 are given in Table 49.

Herring oil is prepared from sea herring, chiefly *Clupea harengus,* a species of fish closely related to the pilchards used in the preparation of sardine oil. The oil possesses properties similar to those of sardine oil; and, as the methods of manufacture are similar, these oils will be considered in the same section.

In America, herring oil is prepared in Maine and Alaska, the bulk of the oil being produced in Southeastern Alaska where four factories operated in 1922, utilizing herring offal, immature herring and any surplus of fish. In that year 450,362 gallons valued at $150,144 were manufactured in the United States. It is one of the novel industries of that section, being introduced chiefly to meet the demand for fish meal.

Herring oil is also manufactured in England, Scotland, Germany and

Norway from the waste of the smoking and salting industry and the surplus fish.

Much herring oil is produced in Japan. The chief centers of the industry are Hokkaido, Karafuto, Chiba and Ishikawa.

Methods of Manufacture.

In California, sardine oil is prepared either by pressing the cooked scrap or by extracting the cooked, dried scrap with gasoline. The press type of plant is the more common. Since the quantity of fish received daily is much less than that received at a menhaden oil factory, the sardine oil factories are much smaller. Moreover, these plants utilize any sort of fish waste obtainable. Large quantities of waste from the tuna canneries are received at certain seasons of the year.

Press Type of Plant.—The sardine offal is conveyed from the storage bin on the top floor of the factory to the cooker on a belt conveyor. The cooking is usually done in a steam chamber or stationary horizontal cylinder about 2.5 feet in diameter and 18 feet long insulated with asbestos to conserve the heat. The fish waste is carried through this steam chamber at a uniform speed by means of a revolving screw whose revolutions are so timed that the scrap remains in the chamber about 15 minutes. This revolving screw conveyor carries the cooked fish on to the press.

The continuous screw type of press is the one commonly used for pressing sardine scrap in California. The press consists of an auger-shaped screw working in a perforated metal jacket. A press capable of handling about 30 tons of offal daily is about 7 feet long. The first 3 feet of the press casing is of lighter construction with relatively larger holes for the purpose of draining off the free water. A second screw revolves more slowly in the last four feet of the press. This slowly revolving screw works against a deeply beveled stationary disk which blocks the forward progress of the material and allows it to escape very slowly in the form of a coarse paste scraped from the beveled edges of the disk. The oil and water are caught in a drip pan and piped to the separating tanks.

Separation of Oil and Water.—To effect the separation of the oil from the water the drippings from the press are run through a series of five settling tanks; Scofield[10] has described this process as follows:

> In the first tank the water and refuse particles are allowed to settle to the bottom and are drained off into the ocean. The oil is syphoned over into the next tank in the series where the gravity separation of the fat from the oil is begun. The top or first oil in the last settling tank is a fairly clear oil but the complete clarifying of the oil by settling out the fat may require several weeks and is unnecessary. The clear oil from the top of the last tank has been used successfully as a paint oil without further refining or the use of a drier in the paint, but this is not the usual practice. The oil is shipped in barrels to paint factories where it is processed for use in paints. . . .
>
> Below the clear oil in the tanks is found the cloudy fatty oils and thick fat material called stearine. The heavier stearine is called "foots." The stearine is sold for use in the manufacture of soap. As stearine contains from 40 per cent to 50 per cent oil it is sometimes heated and more oil drawn off, but it usually goes direct to the soap manufacturer.

[10] *California Fish and Game*, *7* (1921), 207-217.

Yield of Oil.—The yield of oil obtained varies from day to day and from month to month and depends not only upon the fluctuations in the fat content of the sardines themselves but upon the proportion of whole fish and of anchovies which the waste contains. Anchovies contain less oil than sardines, and whole sardines and anchovies contain less oil than offal. The yield of oil varies from about 7 to 27 gallons per ton, with an average yield of 10 to 12 gallons per ton of offal.

Volatile Solvent Process.—Two by-products plants of Southern California obtain the fish oil by the extraction of the cooked dried scrap with gasoline followed by the distillation of the solvent from the solution. Scofield[10] has described this type of by-products plant operating on sardine offal purchased from the canneries as follows:

> The sardine offal is transported to the plant by auto truck and dumped into a storage bin from which a belt conveyor with small buckets carries the material to the drier. The conveyor is filled by hand so that the amount fed in may be varied according to the directions given by the man operating the drier.
>
> **Drier.**
>
> The drier (cooker and drier combined) is a large revolving horizontal cylinder, 40 feet long and 4 feet in diameter, operating on the same general principle as the drier described above, which merely dried the cooked and pressed material. This drier first cooks and then dries the fresh offal from the storage bin. The heat is provided by a burning spray blast of mixed steam and oil, the draught being created by a tall stack. In this case the flame is shot directly into the drier. The conveyor empties the offal directly into this flame and the four or five longitudinal cleats of the revolving drier keep it tumbling. The amount of flame and heat may be delicately regulated by adjusting the amount of oil and steam sprayed in. When fairly dry material is being received, the flames extend only two or three feet into the cylinder, but with particularly wet material the flames may be shot into the drier a distance of eight or ten feet. The wet offal is tumbled in the flame during several revolutions of the cylinder till the material is sufficiently heated to cook the flesh free from the bones. As the moisture is absorbed by the hot air blast and the flames, the dried fish material, being lighter in weight, is blown toward the back end of the drier. The cylinder is set up with only a very slight pitch downward, the draught being sufficient to carry the fish through. The fish remains in the drier about thirty minutes from the time of entering the flames till it is blown to the back end of the cylinder as dry meal. The offal is not only cooked and dried in the cylinder, but the tumbling of the dried material breaks it up into a coarse meal, the chunks of which are usually no larger than a pea. In this drying process it is essential that the supply of material being fed into the drier be uniform, in order to reduce as much as possible the readjusting of the flame. When a great amount of wet fish is fed in rapidly, the drying is not complete and the product is too moist. If the supply of raw material is reduced suddenly, or is much dryer than the preceding supply, the excessive heat burns the fish into hard cakes and extracts free oil, which collects in the bottom of the cylinder and sometimes catches on fire.
>
> **Recovery of Meal from Drier.**
>
> As the back end of the cylinder is open, the meal is blown out into a small catching passageway which has a small hole in the floor to allow the heavier particles of the meal to escape, but much of the meal is in the form of dust and is carried past this opening by the air current. In order to recover this dust, the air current is led through three dust chambers before it escapes up the stack. The opening into the first chamber is near the top and the outlet near the floor, so that the heavier dust settles to the floor. In the second dust chamber the intake is near the floor and the outlet near the top, so that the finer dust settles in this second chamber. The air current then drops again in a third chamber before escaping up the stack, so that all but a negligible amount of very fine dust is recovered. The

dust chambers are emptied once or twice a day by opening a door in the side wall and shoveling up the accumulated fine meal. The dried meal is known as "unfinished stuff," as it has yet to be processed to remove the oil. This unfinished stuff is spread on the concrete floor to cool before it is elevated to the second story of the building in readiness for the next step in the process, the extraction of the oil.

Extraction Tank.

The extraction tank is a heavy cylindrical steel tank about nine feet in diameter and about fourteen feet high. The tank is filled through a door in the top to within eighteen inches of the top with the dry unfinished meal. Gasoline is then sprayed in from the top through a perforated pipe till the tank is filled with gasoline sufficient to cover the meal. The tank full of meal and gasoline is then heated by introducing steam at the top of the tank. The heat is said to be about 325 degrees and is continuous for an average of about eight hours. The gasoline begins to take up the oil of the fish meal even before the meal is thoroughly heated, so that the process of draining off the mixed gasoline and oil is begun soon after the steam is introduced. The bottom of the tank is a sheet of steel perforated to allow liquid to drain through it. Under this metal sheet there are alternating layers of charcoal and gunny sacking to catch and hold particles of meal, so that the liquid may be drained off as pure as possible. After this oily gasoline is drained out, the tank is again flushed with a fresh supply of gasoline, which is also drained off. A small door in the side of the tank, even with the metal floor, is then opened and the meal pulled out.

Recovery of Oil.

The liquid drained from the extraction tank is carried by pipe into a smaller tank called the evaporating tank, which is about 12 feet long and 5 feet in diameter. It is provided with a large steam coil capable of heating the liquid to 300 or 325° (F.). The heat volatilizes the gasoline and a pipe at the top of the tank carries off the gas thus formed. After about 4 hours practically all the gasoline is driven off, leaving only the fish oil remaining in the tank. If much gasoline is left in the oil and the oil is later refined, a serious explosion is apt to result, so that it is essential to drive off all the gasoline possible. The oil is then blown out of the tank by steam pressure and conducted by pipe to a storage tank. The oil is later deodorized by heating to about 600° (F.), which also removes practically all of the moisture and other volatile impurities. The oil is then ready for shipment to the paint manufacturer.

Recovery of Gasoline.

The volatilized gasoline escapes from the evaporating tank in a pipe that is run through a condenser or coiled pipe in a bath of running cold water. Ocean water is particularly good for cooling the condenser pipe. The condensed gasoline drains into a storage tank and is ready for use again in the extraction tank.

Characteristics of Sardine Oil.

American Pressed Oil.—Light colored oil with low free fatty acid content and low unsaponifiable matter is considered the best grade and commands the highest price. While much oil is left in the pressed scrap (8 to 10%) the quality of that obtained is much better than that of the oil extracted with gasoline by the process outlined above. Analyses[10] of pressed oil show that its impurities vary within the following limits:

Free fatty acids	0.5 to 1.5%
Moisture and volatile matter	0.1 to 0.7%
Insoluble impurities	a trace to 0.03%
Unsaponifiable matter	0.2 to 0.9%

Gasoline Extracted Oil.—The yield of oil by the gasoline extraction process is about 20 gallons per ton of offal, but the color is always dark brown or black because of scorching by the flame blast. Because of its dark color, the chief use of this oil is in the manufacture of colored paints. Gasoline extracted sardine oil contains very little of the heavy fatty materials as foots or stearine.

European Sardine Oils.—Fahrion's analyses of European sardine oils are given in Table 51.

Sardine oil is used in Europe in the leather industries and for making soap.

Japanese Sardine Oil.

In 1918, Japan produced over $8,000,000 worth of fish oil. A considerable proportion of this oil was sardine oil which is marketed either under that name or as "fish oil."

Japanese "sardine oil" or Japanese fish oil is obtained chiefly from a pilchard called the *ma-iwashi* (*Clupanodon melanostocta*). After chopping, the fish are boiled with water, the oil then separates on top. When many fish are obtained and there is a shortage of labor, the fish are allowed to rot in heaps; much of the oil flows out and the remainder is obtained by pressure. The oil obtained by the latter process has a very dark color and nauseous taste, whereas that obtained by cooking the fish is of high quality. The crude oil contains a large amount of "stearine." It is refined in Yesso and Yokohama by heating to 50°-60° C. for an hour. Upon cooling, it separates into three layers, viz.: clear oil, solid fat, and a sludge consisting of water and solid particles of fish. The solid fat or stearine is sold as "refined fish tallow" for use in currying leather.

TABLE 51

CHARACTERISTICS OF EUROPEAN SARDINE OILS

	I Iodine Value	II Acid Value	III Insoluble Acids + Unsaponifiable	IV Oxidized Acids, Per Cent	V Unsaponifiable, Per Cent	VI Fatty Acids Freed from Oxidized Acids, Per Cent	VII Molecular Weight of VI	VIII Neutralization Value of the Fatty Acids Freed from Oxidized Acids
Sardine oil, yellow	191.7	19.2	95.60	0.61	0.48	94.51	285.7	185.2
Sardine oil, red	167.9	21.7	96.55	1.35	1.01	94.19	297.7	177.2
Sardine oil, reddish yellow	160.9	4.6	97.08	0.94	0.63	95.51	299.5	179.5

Tsujimoto[11] examined Japanese sardine oils of known purity, obtaining the following results:

Specific gravity at 15.5 C.	0.9316–0.9347
Saponification value, mgs. KOH	194.8–196.2
Iodine value %	180.6–187.3
Refractive index at 20° C.	1.4802–1.4808
Butyro-refractometer at 40° C.	56°–61°

On brominating the mixed fatty acids, 47.09, 44.24 and 44.88 per cent respectively of clupanodonic octobromide were obtained from three different samples of the oil. This corresponds to a 13.34-14.20 per cent of clupanodonic acid in the mixed fatty acids.

Manufacture of Herring Oil.

In general, the same processes are used in the preparation of herring oil as have been described under sardine oil, in fact, in many factories, sardine and herring waste are mixed before reduction into oil and scrap. Therefore, a special consideration of the methods of production of herring oil will not be necessary.

Composition of Herring Oil.

A sample of pale herring oil examined by Lusskin[12] had a specific gravity at 15° C. of 0.9240, and acid value of 2.4, and an iodine value of 137.9. Since the acid number depends to such a large extent upon the process and the care used in its manufacture this factor is variable, sometimes running as high as 42 per cent.

Lexow[13] fractionally distilled the fatty acids obtained from herring oil and obtained the following percentages of acids:

Myristic	6.8%
Palmitic	9.0
Zoomarinic	9.1
Stearic	3.5
Oleic	8.0
Isolinolic	11.9
Gadolinic	11.7
Erucic	12.3
Clupanodonic $C_{20}H_{30}O_2$ $C_{22}H_{34}O_2$	7.4
Non-identified	6.3
	86.0 (residue 14%)

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[11] *J. Coll. Eng. Tokyo Imp. Univ., 4* (1906), 1.

[12] *8th International Cong. Applied Chem.*, 1912, *12*, 155-8.

[13] *Tidskrift Kemi, 15* (1918), 309-24.

Salmon Oil.

The Industry.

Salmon oil is prepared from the offal resulting from the cleaning of salmon preparatory to canning or salting. The industry is located principally in Oregon, Washington, and Alaska. Salmon oil and scrap were manufactured in 1922 in Astoria, Oregon; Cultus Bay, Washington; Hawks Inlet, and Petersburg, Alaska, from salmon offal and stale fish. In 1922, but 25,989 gallons of salmon oil valued at $9,435 were produced in these two states and Alaska. The industry is as yet in its infancy. Large quantities of salmon waste are still thrown away. When a low priced simple equipment is invented, which will handle small quantities of salmon economically, much larger amounts of oil and scrap will be produced. Turrentine[14] has estimated that the total annual salmon cannery waste on the Pacific Coast is 140,210 tons with a value (at $15 a ton) of $2,103,150.

Methods of Manufacture.

The process in common use is called the "batch" type to distinguish it from the "continuous" method which has been described under the heading *Menhaden Oil.* The process is carried out in the same steps as the continuous process; however, the material does not pass continuously and automatically through the apparatus.

Cooking.—The usual method of carrying out this operation is by heating with direct steam in an upright cylindrical retort either without steam pressure, or under pressure up to 110 pounds, and ordinarily without stirring devices. The manner in which the steam is admitted and the length of the cooking period vary from plant to plant. In some cookers, the steam is injected at the bottom and allowed to permeate the mass of waste; when it appears and issues freely from the top the charge is considered sufficiently cooked. In other cases, the cooking is continued for 12 hours under 20 pounds steam pressure. A later type is a horizontal cooker having a cylindrical center with conic section ends. The steam enters through an extra heavy pipe which forms the axle of the cooker. It is connected with a gearing by which it is turned. The cooking is usually effected in about 25 minutes with 100 pounds of steam. Steam jacketed cookers have come into use recently. It is claimed that these cookers reduce the loss of protein due to its hydrolysis by the steam.

If the cooking is effected in an upright cylinder, the charge is usually allowed to stand to settle, during which much oil rises to the surface and is drawn off. Whether or not the cooked fish is allowed to settle, it is admitted to the presses hot. In some cases, the charge is run into a storage vat or "slush box" which is provided with steam coils so that the material may be kept hot until needed for the presses. This system makes the rate of cooking independent of that of pressing.

Pressing.—In this industry, the hydraulic type of press is in common use. Turrentine[14] has described the operation of this type of press as follows:

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[14] *U. S. Dept. Agr., Bull. 150* (1915).

A framework of 1-inch strips of wood inclosing a square of about 3 or 4 feet is placed on a truck and over it is thrown a square of the burlap. This makes a shallow receptacle, which is filled to the depth, perhaps, of about 3 inches with the material to be pressed. Then the loose edges of the burlap are folded over on top of the material so that it is entirely covered. On top of this is placed a square, of about the same dimensions, of wooden slats, held together by a suitable framework. On the slats is placed a second frame and a second square of burlap, which receives in like manner another charge of material. This operation is repeated until a stack of batches of material held thus in sections of burlap is built up of sufficient height to fill the press. Sheet-iron plates may be substituted for the wooden slats.

In charging, the truck which is to support the charge is wheeled beneath the cookers or the "slush box." For this purpose a track is built from the press to the cookers. The cooked fish, by the manipulation of cocks and a movable spout, is permitted to flow upon the receptacle arranged for it. When the charge has been completed, the truck with its burden is wheeled into the press. The pressure is applied until the maximum power of the press has been reached, or until no further amount of water and oil can be removed.

Separation of Oil from the Water.—The oil and water expressed from the cooked salmon are run into vats, where, upon standing, the oil rises to the surface and the fine sludge settles out. The oil and water emulsion is usually difficult to break, because of the presence of glue and lecithin, and, therefore, is ordinarily kept hot until the separation is effected. Some manufacturers use centrifugal separators but these are not popular as they have to be stopped and cleaned out frequently. Others use sulphuric acid to "cut" the emulsion and effect a clarification.

Characteristics of Salmon Oils.

The bulk of the salmon oil produced on the Pacific Coast ranges from 5 to 15 per cent of free fatty acid. This high acid content is largely caused by the poor methods of separation of the oil and water emulsion, as a slow hydrolysis of the oil takes place during the breaking of the emulsion. Some of the modern separation processes produce light colored oil containing less than 2 per cent of free fatty acid.

The constants of the oil and of the fatty acids depend to a large extent upon the species of salmon from which the oil was made. Chinook or king salmon oil has the lowest iodine number and the lowest content of highly unsaturated fatty acids, whereas the medium red or coho salmon oil possesses the highest iodine number and the highest content of highly unsaturated fatty acids. Some characteristics of the various salmon oils are presented in Table 52.

Uses.

Commercial salmon oil is a high-grade fish oil and is usually of light color. Its price is often somewhat higher than that of menhaden oil.

Salmon oils have lower iodine numbers than menhaden oil, yet their properties are similar enough so that they are used for the same purposes. One by-products factory has been manufacturing a complete line of paints and stains from salmon oil. This concern has been very successful in deodorizing the oil.

TABLE 52

CHARACTERISTICS OF SALMON OILS *

Kind of Salmon		Iodine Numbers		Insoluble Bromides	
Common Name	Scientific Name	Lowest	Highest	Lowest	Highest
Red, Sockeye, or Blueback	*Oncorhyncus nerka*	140.72	148.10	32.61	37.35
Chinook, King, or Spring	*Oncorhyncus tschawytcha*	126.62	134.48	23.86	31.06
Medium Red, Coho, or Silverside	*Oncorhyncus kisutch*	152.51	166.40	43.07	59.31
Humpback, or Pink	*Oncorhyncus gorbuscha*	153.58	.....	40.17	....
Chum, or Dog	*Oncorhyncus keta*	133.10	147.75	27.59	35.33

* Bailey and Johnson, *J. Ind. Eng. Chem.*, *10* (1918), 999.

Oils of Minor Importance.

The oils which have been considered above, viz.: menhaden, sardine, salmon and herring, are the most important fish oils. Many other oils are obtainable on the market in considerable quantities, for instance albacore, dab, mackerel, and yellowtail oils. In most cases these oils are mixed with other oils and sold under other names or simply as "fish oil." The methods of obtaining these oils are the same as those which have been described.

In Table 53 are presented the constants of many of these oils.

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TABLE 53

Fat Constants of Fish Oils of Minor Importance

Oil	Source	Refractive Index 30° C.	Specific Gravity	Saponification Value	Iodine Value	Acid Value	Observer
Abura-garei	*Cynopselta dubia*	......	0.9181 (15.4° C.)	182.9	95.8	6.1	Nakatogawa
Akajei	....	......	......	186.98	161.95	1.72	Lewkowitsch
Albacore	....	......	0.9327	190.0	184.0	0.37	Gardner
Anchovy	*Engraulis encrasicholus*, Pond	......	......	188.1	152.4–169.3	....	Fahrion
Bluefish	*Pomatomus saltatrix*	1.4749	0.9353 *	185.1	118.9	12.4	Clark and Almy
Bonita	*Sarda sarda*	1.4755	0.9389 *	178.7	126.8	28.6	Clark and Almy
Bonito	*Gymnonsarda affinis*, Cantor	......	......	184.69	208.92	15.8	Lewkowitsch
Butterfish	*Poronotus triacanthus*	1.4732	0.9213 *	190.5	138.2	3.0	Clark and Almy
Carp	*Cyprinus carpio*	......	0.9107 (27.2° C.)	202.3	84.3	0.18	Zdarek
Channel cat	....	1.4741 (25° C.)	0.9234	192.0	123.0	10.9	Gardner
Cramp-fish	*Torpedo marmorata*	......	0.9090	142.2 ?	107.3	2.15	Bull
Croaker	*Micropogon undulatus*	1.4724	0.9312 *	191.2	115.8	....	Clark and Almy
Eel	....	......	......	200.60	107.42	0.0	Lewkowitsch
Flounder	*Pseudopleuronectes americanus*	1.4820	......	197.6	118.9	....	Clark and Almy
Haddock	*Melanogrammus æglefinus*	1.4940	......	.....	133.4	....	Clark and Almy
Hoi	....	......	0.919 (15.5° C.)	169.0	124.0	....	Liverseege
Kingfish	*Menticirrhus americanus*	1.4663	0.9146 *	195.7	85.4	3.4	Clark and Almy
Ling	*Urophycis sp.*	......	......	.....	80.8	....	Clark and Almy
Mackerel	....	......	......	191.6	167.4	1.7	....
Mackerel pike	....	......	......	184.74	139.81	14.47	Lewkowitsch
Pilchard	*Alausa pilchardus*	......	......	185.3–186.1	150.0	....	Buttenberg and Stuber
Pollack	....	......	......	170.0	136.1	....	Henseval and Huwart
Porgy	*Stenotomus chrysops*	1.4736	0.9270 *	188.4	136.2	7.2	Clark and Almy
Sea bass	*Centropristes striatus*	1.4731	0.9224 *	191.7	132.0	2.2	Clark and Almy

* 25/25° C.

TABLE 53—*Continued*

FAT CONSTANTS OF FISH OILS OF MINOR IMPORTANCE

Oil	Source	Refractive Index 30° C.	Specific Gravity	Saponification Value	Iodine Value	Acid Value	Observer
Shad	*Alosa sapidissima*	1.4716	0.9158 *	186.6	119.1	8.8	Clark and Almy
Silver hake	*Merluccius bilinearis*	1.4797	0.9397 *	186.5	159.0	10.1	Clark and Almy
Spanish mackerel	*Scomberomorus maculatus*	1.4719	0.9201 *	182.5	136.7	3.2	Clark and Almy
Sprat	*Clupea sprattus*, Cuv.	......	0.9274	194.5	122.5–142	....	Henseval and Deny
Stickleback	*Gasterosterus trachurus*	......	......	.....	162.0	21.6	Fahrion
Striped bass	*Roccus lineatus*	1.4748	0.9278 *	196.1	134.4	6.4	Clark and Almy
Sturgeon	*Accipenser sturio*	......	0.9236 (15° C.)	186.3	125.3	0.23	Bull
Sunfish	*Mola mola, L.* *Orthagoriscus mola, Bl.*	......	0.901	147.6 ?	102.7	....	Bull
Tautog	*Tautoga onitis*	......	......	.....	127.5	....	Clark and Almy
Tilefish	*Lopholatilus chamæleonticeps*	1.4753	......	.....	118.8	....	Clark and Almy
Weakfish	*Cynoscion regalis*	1.4717	0.9213 *	187.0	120.8	12.2	Clark and Almy
Whiting	*Alburnus lucidus*	......	0.9268	201.6	127.4	3.98	Bull
Yellowtail	*Seriola*	......	0.9322	190.0	177.0	0.6	Gardner

* 25/25° C.

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Chapter 22.

Liver Oils.

General Characteristics.

Most liver oils resemble fish oils in many respects since they consist chiefly of mixtures of glycerides of various fatty acids. The iodine value of liver oils is relatively high indicating that the percentage of unsaturated fats is high. Cod-liver oil has been shown to contain fatty acids of the formula $C_nH_{2n-8}O_2$, one of which may be clupanodonic acid, the highly unsaturated fatty acid, characteristic of fish oils.

However, liver oils usually contain more unsaponifiable matter than fish oils. Cholesterol is a characteristic constituent of cod-liver oil. It may be obtained by recrystallizing the unsaponifiable matter from alcohol. Liver oils dry more slowly than most fish oils, partly because of their higher content of unsaponifiable matter and partly because of the nature of the unsaturated fatty acids. Most of them do not dry to hard, non-tacky films even when driers are present, therefore they do not make satisfactory paint or varnish oils.

A few liver oils, especially shark-liver oils, consist chiefly of highly unsaturated hydrocarbons. These oils may easily be identified by their unusually high content of unsaponifiable matter.

Fresh liver oils dissolved in carbon disulphide give a blue coloration with concentrated sulphuric acid. If the oils are rancid, a purple or dark brown coloration takes the place of the blue. Lewkowitsch states that this is the only color reaction of liver oils which is of decisive importance in the identification of these oils. Drummond and Watson[1] have shown that a large number of liver oils, and other fats of various mammals give this test.

If a solution of a liver oil in chloroform be shaken with a freshly prepared solution of phosphomolybdic acid, upon standing a blue ring is formed at the zone of contact of the two layers. This test is useful in distinguishing fish-liver oils from other animal oils as marine animal liver oils[2] are the only animal oils giving this test.

Cod-Liver Oil.

Location of Industry.—Although a cod-liver oil industry has existed in the United States for many years, it has never assumed important proportions. In 1921, but 6,015 gallons of medicinal cod-liver oil valued at $3,965 and 43,757 gallons of liver oil valued at $16,193 were produced. All of this oil was prepared in Maine and Massachusetts. Although the Pacific Coast has an important cod industry, little or no use is made of the livers. The statistics for 1922 are given in Table 49. Gloucester, Massachusetts, is the most important cod-liver oil center in the United States.

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[1] *Analyst, 47* (1922), 341-9.

[2] See Lewkowitsch, Chemistry and Technology of Oils, Fats and Waxes, 6th Edition, *1*, 507. London, 1921.

Norway produces large quantities of cod-liver oil. In 1920, this country produced 1,318,922 gallons of the medicinal grade and 135,982 gallons of cod oil. The most important cod-liver oil centers are the Lofoten Islands and Finmarken.

Other countries possessing important cod-liver oil industries are the following: Iceland, Newfoundland, Canada, Scotland and Japan.

In 1922, Iceland produced 513,160 gallons of medicinal oil and 177,200 gallons of cod oil. 282,480 gallons of the medicinal oil were prepared by steaming the livers, the balance being raw medicinal oils.

Hokkaido and Karafuto are the principal centers of the Japanese industry.

Methods of Manufacture.

Medicinal Oil.—In the early days of the industry, the livers were thrown into barrels and allowed to decompose until the liver cells burst and the oil exuded. From time to time the oil was skimmed off and saved. In winter, the first oil obtained was light in color and was called raw medicinal oil. When the putrefaction of the livers had progressed further, the oil exuded was darker in color and was termed brown or cod oil. When no more oil exuded, the residue was thrown into an iron kettle and heated over an open fire. By this process the remainder of the oil was obtained. The decomposed liver tissue remaining, called "graxe," was used as fertilizer. The oil obtained by the final heating was very dark, almost black, with a greenish fluorescence by reflected light, and was sold as cod oil for industrial purposes.

The raw medicinal oil prepared by this crude process possessed a strong odor and a nauseous taste with which cod-liver oil is commonly associated in the popular mind.

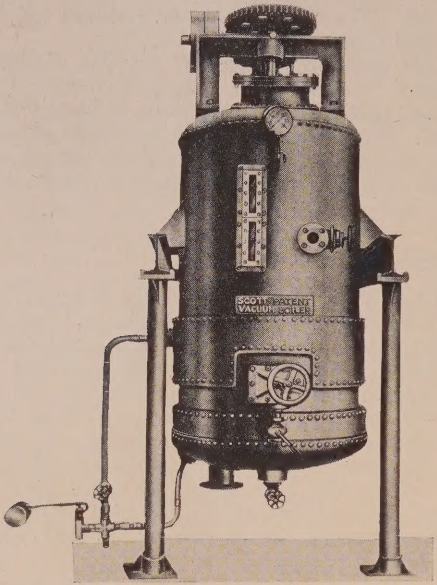
Such methods of production of medicinal oil have largely been discarded for more rapid and more sanitary means. In Norway, the fresh livers are placed in tin-lined vessels provided with open steam coils,, soon after they have been taken from the fish. Low pressure steam is blown into the livers, causing the oil cells to burst, freeing the oil.

In America the cod, haddock, and other ground fish are eviscerated as soon as they are brought on board the schooners. The livers are collected in barrels and sold to the oil factories immediately upon arrival in port.

Steam jacketed kettles or vats are commonly used for the rendering of the oil. Medicinal oil is prepared in Massachusetts only during the late fall and winter months when it is so cold that the livers are received in an absolutely fresh condition. The livers are carefully selected and handled during the preparation of the oil. One plant operates a small cold storage plant to keep the livers from decomposing on warm days during the pressing of the livers in the bay presses.

Recently vacuum cod-liver "boilers" have been introduced. This process permits the rendering of the oil at a lower temperature, and thus the product is improved in color and odor. A special vacuum cod-liver oil boiler is shown in Fig. 159.

Cod Oil.—Cod-liver oil, not intended for medicinal use, is termed cod oil by the trade. In the manufacture of this grade of oil, the precautions taken in the preparation of the medicinal grade are not necessary. For the preparation of light colored oil, fairly fresh livers must be used. If the livers have putrefied, it is very difficult to obtain any other than dark brown oil.



Courtesy Ernest Scott and Co., Ltd.

FIG. 159.—Vacuum cod-liver boiler. The bottom part of the boiler is steam jacketed and the heat applied can be controlled to any desired point. Fresh livers can be rendered in two hours. The oil obtained is decanted from the boiler by means of an adjustable swivel pipe which can be operated without opening the boiler.

In America, the greater proportion of the cod oil is prepared during the fall and winter, and only a little in the spring. Livers of fish other than cod, such as haddock, hake, cusk, and pollack, are often collected together with the cod-livers and cooked in the same vats. Because of this the commercial cod oil seldom is pure cod-liver oil. The livers are usually cooked in large vats with live steam. Jacketed kettles are occasionally used. The oil which rises to the top during cooking is skimmed off and run into tanks or barrels. After cooking, the livers are placed in canvas bags in bay presses (see Fig. 160) resembling those occasionally used for the separation of menhaden oil (see page 426) from gurry.

In Europe, liver oil manufactured for commercial purposes is divided into two classes: (1) cod-liver oil for technical use called cod oil; (2) "coast cod oil" prepared from cod-livers admixed with livers of other fish chiefly those of hake, haddock, and pollack.

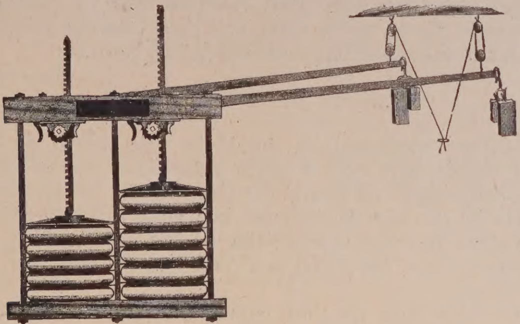


FIG. 160.—Bay oil press for pressing cooked livers.

Electrolytic Extraction.

Recently, a novel process of extraction of oil from livers has been discovered by Rogers.[3, 4] The livers are ground or chopped up and mixed with a warm sodium chloride or other saline solution. The mixture is then pumped usually by means of a gear pump into the base of the electrolytic unit, which consists of a conduit provided with electrodes of opposite polarity extending longitudinally of the conduit, in which it is subjected to an electric current. The mixture emerges from the electrolytic unit as an emulsion of oil in water containing the liver tissue in suspension.

The remainder of the process consists of (a) the separation of solids from the emulsion, the washing of these solids to remove surface oil and the drying of the washed solids, and (b) separating the oil from the electrolyte in the suspension or emulsion.

Rogers states that various electrolytes have remarkably different effects on the oil produced, and that both the color and the odor of the oil may be controlled.

Refining.

The crude cod oil often called "unracked" oil contains much solid fat or "stearine" which separates out on cooling. After allowing the crude oil to stand exposed to the winter's cold for a prolonged period, the oil is separated from the "stearine" either by filtering while cold or by siphoning off the cod oil. Such cod oil is known as noncongealing or "racked" oil.

[3] U. S. Pat. 1,326,968 (1920).
[4] *Chem. Age, 28* (1920), 407.

Both medicinal oil and cod oil are sometimes refined by washing first with a caustic soda solution, then with water, and finally with a very dilute sulphuric acid solution to remove the last traces of alkali. The treatment with caustic soda converts the free fatty acids of the oil into soaps which are soluble in water and are easily removed by the washing. The treated oil is then filtered through fuller's earth to bleach it. In some cases the bleaching is accomplished by exposure in closed glass vessels to the action of sunlight.

Some medicinal oil is also freed from stearine by cooling at a temperature below 0° C. for some time, and then filtering at —10° C. in a manner similar to that used in preparing racked cod oil.

Properties.

Physical.—Pure medicinal oil should be pale yellow or light yellow in color and should have only a slight fishy odor and a not unpleasant taste. "Non-congealing" oil should not set at 0° C. In the examination of medicinal liver oil the taste is the most important test that can be applied. This quality alone indicates whether the amount of free fatty acids is too high and whether any decomposition products of the liver tissue have passed into the oil.

The color, odor, and taste of commercial cod oil for tanning and currying purposes are not important properties as in the case of medicinal oil.

Chemical.—The most important chemical tests used in the examination of medicinal cod-liver oil are the determinations of the acid value, the iodine value, and the Reichert value (Reichert-Meissl value).

The acid number should be low. A large proportion of free fatty acids indicates a strong or rancid taste, and either careless preparation of the oil or old oil and perhaps both. The best steam cod-liver oils contain less than 1.5 per cent of free fatty acids, whereas medicinal oil prepared by the older processes may contain as much as 3 per cent.

The proportion of volatile fatty acids should be low. The better medicinal oils have Reichert numbers below 0.5. Higher Reichert values indicate that the livers employed for the extraction of the oil had not been perfectly fresh; such oil possesses an inferior taste.

The higher the iodine value, the less oxidation can have taken place, and usually the better the oil. The highest number recorded is that of a sample examined by Lewkowitsch and is 198.1. The mean iodine value of a good medicinal "non-congealing" oil is about 167. Since the "stearine" removed during the racking process possesses an iodine number of about 100, a high iodine value sometimes merely indicates that the "stearine" has been separated at an especially low temperature, and a low number that the sample has not been "racked."

The amount of unsaponifiable matter should not exceed 1.5 per cent. Larger amounts than this would indicate adulteration with mineral, shark-liver or other oils containing a considerable proportion of unsaponifiable material. The proportions of unsaponifiable matter found in various samples of cod-liver oil by several observers are given in Table 54.

TABLE 54

Unsaponifiable Matter in Cod-Liver Oils

	Color	Unsaponifiable	Observer
Medicinal	Reddish yellow	0.54	Fahrion
“	Yellow	1.08	“
“	“	0.87	Thompson and Ballantyne
“	Pale yellow	1.44	Fahrion
Steam rendered medicinal	“ “	0.61	“
“ “ “	Almost colorless	0.64	“
“ “ “	Pale yellow	0.98	“
Steam rendered medicinal Japanese	....	2.3–2.8	Bull

The detection of other liver oils in cod-liver oil is very difficult. In many cases chemical means of identifying other oils are not available. Adulteration with some liver oils can be detected by the taste alone. Pollack-liver oil has such an unpleasant taste that its presence in relatively small amounts may usually be noted. Shark-liver oils may usually be detected by the low proportion of ether-insoluble bromides yielded by the fatty acids. Moreover, if shark-liver oils are present in considerable quantities, cetyl alcohol may usually be isolated, since most shark liver oils contain some spermaceti.

Table 55 by Thomson and Dunlop[5] shows the comparative characteristics of cod-liver oil and various other liver oils, prepared from fresh livers, with which it is occasionally adulterated.

Therapeutic.—Cod-liver oil or its emulsions are used medicinally in the treatment of all forms of malnutrition, various forms of tuberculosis,

TABLE 55

Characteristics of Cod and Other Liver Oils

	Specific Gravity at 15° C.	Free Fatty Acids, Per Cent	Saponification Value	Unsaponifiable	Iodine Value	Butyro-refractometer	
Cod (West Coast, Scotland)	.9248	0.20	186.0	1.06	153.7	75.7	66.7
Cod (unknown)	.9247	0.19	185.1	1.02	156.5	76.0	. . .
Cod (East Coast, Scotland)	.9263	1.20	187.9	1.04	167.3	78.0	69.0
Ling	.9240	0.34	187.2	1.00	151.8	75.0	. . .
Hake	.9256	1.05	190.7	1.38	154.0	76.0	. . .
Coalfish	.9261	0.27	187.2	1.14	161.1	77.0	. . .
Whiting	.9290	0.65	187.9	1.06	184.2	81.0	72.0
Haddock	.9290	2.37	187.2	1.30	186.4	81.0	72.0
Skate	.9298	0.33	187.9	1.08	191.1	82.5	73.5
Dogfish	.9179	Trace	169.7	8.40	126.4	71.2	62.5

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[5] A paper read before the Association of Public Analysts of Scotland, June 5, 1905.

chronic rheumatism, gout and rickets and other diseases of the bones. In regard to its action Ellingwood[6] says:

> It increases the appetite, improves the quality of the blood and increases the number of red corpuscles. It increases the power of the heart and the strength of the pulse, adding at the same time to the general strength and weight. It materially assists in the elimination of morbific material—retrograde waste—from the blood, and exercises a beneficial influence over scrofulous, syphilitic, tubercular and other cachexiæ.

Formerly the therapeutic value of cod-liver oil was ascribed to the biliary substances which have since been found to be of secondary products derived from the decayed cellular matter of the tissues. But since the best medicinal oils do not now contain these substances which formerly imparted such a nauseous taste, these bases cannot be the valuable medicinal constituents.

Some writers have ascribed the therapeutic value of the oil to its iodine content. Lewkowitsch[7] has said that its medicinal effect was due to the facility with which it is hydrolyzed or digested. This is ascribed to the peculiar constitution of its unsaturated fatty acids. Another theory, which he advances, is that it supplies those highly unsaturated acids (clupanodonic) which have been shown to occur in the phosphatides of the heart muscles and the liver. The weak organism unable to produce for itself the unsaturated fatty acids has them supplied artificially by the liver oil.

The discovery of the vitamins (see page 276) enabled chemists to explain the remarkable nutritive and therapeutic properties of this oil. Cod-liver oil is the richest known source of the fat-soluble vitamins. Zilva and Miura[8] examined a sample of crude unrefined cod-liver oil and said that it was 250 times as potent a source of these vitamins as butter, which is a food of high fat-soluble vitamin content. The vitamin content of cod-liver oil varies according to the process of manufacture, and the vitamin content of the livers from which it was made.

Drummond and Watson[1] have shown that the vitamin content of liver oils is associated with the unknown substance which gives the purple color reaction of these oils with sulphuric acid (see page 442) and have suggested that this test may be used as a rapid means of estimating the fat-soluble vitamin content of various oils. They have shown that cod-liver oils which give a faint color reaction with sulphuric acid produce relatively little growth in young rats on a diet deficient in these accessory factors and vice versa.

Since the nutritive and therapeutic properties of cod-liver oil are due to its content of the antirachitic vitamin and vitamin A, it behooves manufacturers of medicinal oil to use special precautions not to destroy these components during the preparation, refining, and storage of the oil. The first results of experiments to determine the stability of the vitamins seem to indicate that fat-soluble A could withstand heating for 100° C. or somewhat higher for considerable periods. Recently it has been shown

[6] Therapeutics and Pharmacognosy, Evanston, 1915.

[7] Chemical Technology and Analysis of Oils, Fats and Waxes, *2*, 448. London, 6th Ed., 1922.

[8] *Lancet, 200* (1921), 323.

that this is true only when the heating is effected in the absence of air, and that when fats and oils are heated in the presence of air, the destruction of this vitamin is rapid.

McCollum, Simmonds, Becker and Shipley[9] have recently shown that cod-liver oil with air bubbling through it heated to 100° C. for 12 hours or more does not cure xeropthalmia in rats, yet it retains its power to cause the deposition of calcium in the bones of young rats which are suffering from rickets. This indicates that oxidation destroys fat-soluble A without destroying another substance which plays an important rôle in bone growth. They conclude that cod-liver oil, shark-liver oil, and burbot-liver oil are highly effective for curing xerophthalmia, for protecting the body against the effects of a deficiency of calcium, and for the deposition of lime salts in rachitic bones. These experiments indicate the existence of a fourth vitamin whose specific property is to regulate the metabolism of the bones.

The process of hydrogenation destroys the fat-soluble vitamins. The bleaching of medicinal oil by treatment with hydrogen or other reducing agents, or oxidizing agents (such as ozone) is destructive of the vitamin content and should be avoided.

Therefore, in preparing medicinal oil, the livers should be rendered in as fresh a condition as possible, at a low temperature in vacuo in order to obtain a nearly colorless and pleasant tasting oil and the product should not be bleached with either oxidizing or reducing agents.

Emulsions.—Inasmuch as cod-liver oil possesses a taste unpleasant to many people, many means of administering it have been devised by which its taste is disguised. The most common preparations of this sort are emulsions. These are prepared by emulsifying the oil by means of some emulsifier, such as egg yolk and glycerin, lime water, acacia, glyconin, and the like, and adding a flavoring material, e.g., an essential oil, and water. Thompson[10] gives the following formula:

Cod-liver oil	6 oz.
Oil of wintergreen or any essential oil.........	1 drachm
Mucilage of tragacanth.......................	2 oz.
Orange water sufficient to make..............	12 oz.

Uses of Cod Oil.

In Tanning.—Cod oil has many uses. It is particularly valuable for the manufacture of "chamois" leather. In tanning this grade of leather, the oil is rubbed into the prepared sheepskins, which are subsequently tanned by the oxidation of the oil. The excess oil is recovered by pressing the tanned chamois or by washing the latter with hot water. This expressed oil is known as degras and is largely used by leather makers and curriers. Some degras is especially manufactured for curriers by allowing the cod-liver oil to oxidize in the presence of sheep skin waste. After the oxidized oil has been drawn off, new oil is added to the tanks in which the process takes place, the same sheepskin serving for repeated oxidations.

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[9] *J. Biol. Chem., 53* (1922), 293-312.

[10] Practical Dietetics, New York, 1905.

Sod oil is obtained from the tanned chamois, after the removal of the degras, by washing the leather in a hot sodium carbonate solution. After the skins have been removed, the sod oil is recovered by the addition of sulphuric acid to the liquor liberating the free fatty acids of the oxidized cod oil which are sold under the name of sod oil.

Buff leather is prepared from flat hides by an oil tannage process similar to that used in the manufacture of chamois leather. Occasionally, degras is also obtained from these goods by putting them through a wringing machine.

Buck leather is made from deer skins by a similar process. The skins are, however, stocked with oil for a much longer time, as the penetration of the oil has not been assisted by the removal of the grain.

Currying.—The various operations which are carried out in the finishing of goods tanned for belting, harness, upper leather, etc., to render them pliable and waterproof are known as "currying." The most essential process is that of "stuffing" the goods with oils and fats. The object of stuffing is to coat the tanned hide fibres with fats which lubricate them, and render the leather somewhat pliable, and also, to fill in the spaces between the fibres and thereby give weight and waterproofness. Cod oil, degras, and sod oil are common ingredients of the various stuffing mixtures used in this process. The exact composition of the mixture depends upon the nature of the leather undergoing treatment, the process, i.e., hand stuffing, drum stuffing, etc., and the individual idea of the manufacturer.

Other Uses.—Other uses of cod-liver oil include the manufacture of oiled cloth, and low grade soaps, and for the tempering of steel.

Shark-Liver Oil.

Location of Industry.

Considerable quantities of shark-liver oil are prepared in Iceland. Some shark-liver oil has been manufactured for a long time in India where it is used both medicinally and in the leather industries. At various times, this liver oil has been prepared in the United States. It is now manufactured in North Carolina in connection with the shark leather industry. In recent years, Japanese chemists have taken much interest in the properties of the oils derived from the various species which abound in Japanese waters.

The methods of manufacture of shark-liver oil are identical with those described for cod-liver oil, except that but small quantities are used medicinally, therefore care is seldom taken to obtain tasteless and colorless oil. The fresh livers are either treated with live steam or heated in steam jacketed kettles. The oil rising to the top is skimmed off and the residue is pressed.

The liver of the cub shark (*Carcharhinus commersonii*) is large, and constitutes about 16 per cent of the weight of the whole. A liver rendered by the writer yielded 37 per cent of oil.

The sand shark (*Carcarias taurus*) has a small liver possessing little oil. An 8 pound liver yielded but 20.9 per cent of oil.

Properties.

Physical.—The color, odor and taste of shark-liver oils depend chiefly upon the freshness of the livers used in the extraction and the process of extraction followed. Commercial shark-liver oils vary from light brown to nearly black. Carefully steam rendered oil from fresh livers varies from pale yellow to light brown in color. The odor and taste of such light colored oils is much less than that of the ordinary commercial oils.

Chemical.—The oils obtained from the livers of the various species of sharks fall into two classes depending on whether they consist chiefly of glycerides of the fatty acids, or whether they contain considerable amounts of hydrocarbons. The latter class of shark-liver oils may be distinguished by their low specific gravities and saponification values and high amounts of unsaponifiable matter. Those which consist chiefly of glycerides of the fatty acids resemble cod-liver oil in many of their properties, although most of them contain relatively high amounts of unsaponifiable matter. Two samples of commercial American shark-liver oils analyzed by the author had the following constants:

	"Mud Shark"	"Shark"
Specific gravity at 15.5° C.	0.9120	0.9192
Acid value	0.50	0.87
Saponification value	163.3	175.2
Iodine value (Hanus)	111.9	127.6
Refractive index (40° C.)	1.4680	1.4690
Titer test of fatty acids in degrees C.	15.3°	31.2°
Neutralization value of fatty acids	157.3	172.7
Mean molecular weight of fatty acids	357.0	324.7
Unsaponifiable matter	10.2%	5.34%

These two oils resemble cod-liver oil in many respects.

Tsujimoto [11] found that many of the liver oils prepared from various Japanese sharks contain a liquid hydrocarbon which he named squalene, which has the following characteristics: specific gravity (15°/4° C.) 0.8587; boiling point under 10 m.m. pressure 262-264° C.: N^{20}_{D} 1.4965; iodine value 388.12; formula $C_{30}H_{50}$ forming a dodecabromide $C_{30}H_{50}Br_{12}$, and upon hydrogenation $C_{30}H_{62}$.

Chapman [12] has shown that a new highly unsaturated hydrocarbon is present in the liver oil obtained from two members of the shark family caught off the coast of Morocco. This hydrocarbon, called spinacene, contains 6 double bonds and was given the formula $C_{20}H_{48}$. Its iodine value was 376.2 and it is probably closely related to squalene.

The properties of various shark-liver oils are given in Table 56.

Therapeutic.—Drummond found the fat-soluble vitamins in shark-liver oil, but states that it contained less than the samples of cod-liver oil which he examined simultaneously. However, he does not state from which species of shark the oil was prepared. McCollum, Simmonds,

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[11] *J. Ind. Eng. Chem., 8* (1916), 889.

[12] *J. Chem. Soc. Trans., 111* (1917), 56; *Analyst,* 1917, 141 and 161; *J. Chem. Soc. Trans., 113* (1918), 458.

TABLE 56

Physical and Chemical Characteristics of Certain Shark-Liver Oils

	Species	Specific Gravity	Saponification Value	Iodine Value	Acid Value	Unsaponifiable, Per Cent	Observer
Arctic shark....	*Seymnus borealis*	0.9105–0.9130	146.1–148.5	111.9–114.9	2.6–6.2	20.8–21.8	Bull
Basking "	*Cetorhinus maximus*	0.8839 at 15°/4° C.	102.45	178.3	1.09	41.92	Tsujimoto[1]
Cub "	*Carcharhinus commersonii*	0.9266 at 15.5° C.	187.3	154.5	0.23	1.84	Tressler
Hammerhead "	*Sphyrna zygæna*	....	174.1	155.5	3.32	....	White[2]
Japan "	....	0.9156–0.9177	157.2	128.3–136.0	0.88–1.5	14.4–21.5	White[2]
Japan "	....	0.9158	....	90.0	...	....	Eitner
Japan "	*Pristiurus pilosus*	0.8664 at 15°/4° C.	28.2	309.0	0.32	85.5	Tsujimoto[3]
Japan "	*Centrophorus sp.*	0.8644 at 15°/4° C.	22.98	344.6	0.0	90.17	Tsujimoto[4]
Sand "	*Carcharius littoralis*	....	182.7	213.6	1.52	....	White[2]
Sand "	*Carcharius taurus*	0.9248 at 15.5° C.	180.3	151.7	0.20	1.84	Tressler
Torpedo "	*Tetranarce occidentalis*	....	164.0	111.0	0.92	....	White[2]

[1] *J. Ind. Eng. Chem.*, *9* (1917), 1098.
[2] *J. Ind. Eng. Chem.*, *4* (1912), 106.
[3] *J. Chem. Ind. Tokyo*, *21* (1918), 1015.
[4] *J. Ind. Eng. Chem.*, *8* (1916), 889.

Becker and Shipley[9] found shark-liver oil highly effective for curing xerophthalmia, for protecting the body against the effects of a deficiency of calcium, and for the deposition of lime salts in rachitic bones.

Shark-liver oil is used medicinally to a limited extent in India. Undoubtedly the therapeutic value lies in its high fat-soluble vitamin content. As usually prepared, the oil has a very strong taste. But if it were carefully prepared by rendering the fresh livers at a low temperature in vacuo, it might be prepared so as to make a satisfactory substitute for cod-liver oil.

Researches should be carried out to show which species of sharks have livers of particularly high vitamin A content.

Uses.

The most important use of shark-liver oils is in the tanning industry for the currying of leather. These oils are used unmixed and in admixture with cod-liver oil. Tarpaulins and other oiled cloths are made from the more highly unsaturated oils. Liver oils have been suggested as ingredients of rubber substitutes.[13] Occasionally they are utilized for the manufacture of low grade soaps and in the tempering of steel. Shark-liver oils are sometimes mixed with vegetable paint oils, such admixture being objectionable as liver oils do not dry well.

Dogfish-Liver Oil.

Dogfish abound on both the banks of the North Atlantic and North Pacific Oceans and at various times dogfish oil and dogfish-liver oil have been made in Canada, Washington and Alaska. At one time three factories reduced dogfish to oil and scrap on the Canadian Atlantic Coast (see page 457); two of these were controlled by the Government. At present no oil is being produced.

Properties.

Dogfish-liver oil resembles those shark-liver oils which consist chiefly of the glycerides of fatty acids and which contain relatively small proportions of unsaponifiable matter. A sample obtained in Seattle, Washington, which was examined by the author, gave the following analysis: Specific gravity (at 15.5° C.) 0.9140; acid value 1.20; saponification value 161.9; iodine value 136.0; refractive index (40° C.) 1.4682; titer test fatty acids 26.0° C.; neutralization value of fatty acids 156.7; mean molecular weight of fatty acids 358.0; total unsaponifiable matter 14.24%. An analysis of another sample of dogfish-liver oil is given in Table 57.

Dogfish-liver oils are utilized in the same manner as shark-liver oils.

Liver Oils of Little Commercial Importance.

Skate-liver oil is prepared in Bengal, India. Some is also obtained in North Carolina. A sample of the commercial North Carolina oil analyzed

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[13] R. Zimpel, Germ. Pat. 236,728 (1911).

TABLE 57
ANALYSES OF LESSER KNOWN LIVER OILS

Liver Oil from	Source	Specific Gravity	Saponification Value	Iodine Value	Refractive Index	Acid Value	Unsaponifiable, Per cent	Insoluble Bromides, Per cent	Observer
Angler fish	*Lophiomus setigerus*	0.9268 (at 15°/4° C.)	188.6	154.1	1.4790 at 20°	1.1	1.00	44.13	Tsujimoto
Butterfish	*Poronotus tricanthus*	....	191.4	91.1	....	62.1	. . .	. . .	....
Cusk	*Brosmius brosme*, Müller	0.9222	180.4	130.1	....	0.3	4.92	. . .	Mann
Cuttlefish	*Cephalopoda* ?	0.9316 (at 15°/4° C.)	189.6	177	1.4806 at 20°	3.88	1.14	57.5	Tsujimoto
Dogfish	*Squalus acanthias, L.*	0.9179	169.7	142.7	....	4.84	8.4	. . .	Thomson and Dunlop
"	*Squalus borealis*	0.9303 (at 15° C.)	225	....	....	2.55	0.89	. . .	Henseval and Huwart
Eel	*Anguilla rostrata*	....	191.1	117.4	....	. . .	. . .	. . .	White
Globefish	*Spheroides porphyreus*	0.925 (at 15°/4° C.)	182.2	159.8	1.4785 at 20°	0.88	1.47	46.65	Tsujimoto
Guitar fish	*Rhinobatus schlegelii*	0.9267 (at 15°/4° C.)	182.81	183.67	1.4825 at 20°	2.66	3.15	60.20	Tsujimoto
Ratfish	*Chimæra phantasma*	0.9161 (at 15°/4° C.)	....	113.02	1.4728 at 20°	. . .	8.52	22.4	Tsujimoto
Ray	*Raja clavata (batis)*	0.9345 (at 15° C.)	186.1	178.5	1.4860	4.86	1.48	. . .	Huwart
"	*Trygon pastinaca*	0.9161 (at 15° C.)	160.2	105.7	1.4752	0.75	12.55	. . .	Henseval and Huwart
"	*Raja kenojei*	0.9329 (at 15°/4° C.)	182.69	200.06	1.4843 at 20°	2.02	3.11	65.23	Tsujimoto
Ray, eagle	*Myliobatis aquila*	0.9214 (at 15° C.)	191.8	115.3	1.4760	1.84	2.66	. . .	Huwart
" "	*Myliobatis tobiei*	0.9203 (at 15°/4° C.)	175.18	136.05	1.4773 at 20°	0.83	4.47	33.51	Tsujimoto
" white sting	*Trygon microps*	0.914 (at 40° C.)	194.0	124.7	....	0.98	. . .	. . .	Hooper
" sting	*Dasyatis akajei*	0.9316 (at 15°/4° C.)	183.10	184.50	1.4827 at 20°	1.17	2.94	63.08	Tsujimoto
Shark ray	*Ramphobatis ancylostomus*	0.909 (at 40° C.)	187.4	118.5	....	1.13	. . .	. . .	Hooper
Sawfish	*Pristis perottetii*	0.900 (at 40° C.)	187.1	92.9	....	1.0	. . .	. . .	Hooper
Skate	*Squatina vulgaris*	0.9307 (at 15° C.)	185.4	157.3	....	. . .	0.97	. . .	Lewkowitsch
"	....	0.9298 (at 15° C.)	187.9	191.1	....	0.66	1.08	. . .	Thomson and Dunlop
" (Japanese *Suketo-fura*)	*Gadus chaulcogramus*, Pall.	0.9279 (at 15° C.)	187.9	169.6	1.4798 at 20°	1.18	. . .	40.08	Tsujimoto
Scup	*Stenotomus chrysops*	....	188.9	117.3	....	. . .	. . .	. . .	White
Tuna	*Thynnus vulgaris*	....	....	155.9	....	0.2–34	1.0–1.8	. . .	Fahrion
" (Japanese *Maguro*)	*Thynnus schlegelii*, Steind.	0.9327 (at 15° C.)	185.3	198.9	1.4837 at 20°	20.8	. . .	51.5	Tsujimoto
"Uchiwa zamé"	*Discobatus sinensis*	0.9324 (at 15°/4° C.)	179.36	192.54	1.4826 at 20°	2.36	2.60	62.96	Tsujimoto
Whiting	....	0.9290	187.9	184.2	....	1.3	1.06	. . .	Thomson and Dunlop

by the author had the following constants: Specific gravity (15.5° C.) 0.9300; acid value 0.75; saponification value 194.3; iodine value (Hanus) 122.5; refractive index (40° C.) 1.4700; titer test of fatty acids 33.3° C.; neutralization value of fatty acids 183.7; mean molecular weight of fatty acids 305.5; total unsaponifiable matter 1.70%.

Other analyses of skate-liver oils and of lesser known liver oils are presented in Table 57.

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Chapter 23.

Fish Scrap Fertilizer.

The Industry.

The use of fish as fertilizer in America antedates the arrival of the first white settlers. The American Indians were aware of the value of decomposing fish as a plant nutrient for, where fish were plentiful, they buried a fish near every hill of corn. The early settlers utilized fish in much the same way, placing whole fish on the ground. Menhaden, alewives, and herring were plentiful and were commonly used along the coast as manure.

When the value of menhaden oil was discovered, the fish were placed in casks, covered with water, and compressed with weighted boards. The fish soon became putrefied, the oil cells disintegrated, and the oil rose to the surface and was skimmed off from time to time. The residue was spread on the land as a manure. Later the fish were boiled in kettles with water and pressed. The residue was spread in the open air to dry. This constituted an important advance and was the beginning of the present fish scrap industry for the product could be stored or shipped and was in a form easily applied to the land.

In recent years, the menhaden-scrap industry has been well organized; large factories have been erected which handle efficiently even the large catches. This industry is located along the Atlantic Coast from Massachusetts to Florida, chiefly in New York, New Jersey, Virginia, North Carolina and Texas. The sardine and tuna scrap industry has attained considerable proportions in California. Over $116,000 worth of fish scrap (prepared chiefly from salmon) was produced in 1921 in Washington and Oregon and a smaller quantity in Alaska. In several states, small amounts of fish meal and fertilizer are prepared from other fish.

The production statistics for 1922 for menhaden scrap and for scrap from other fish are given in Tables 50 and 58. Since fish scrap is sold for use both as feed and fertilizer no separate statistics as to the amounts of meal and fertilizer produced are obtainable.

The fish waste from the larger markets forms the chief source of the raw material for the manufacture of fish fertilizer in the United Kingdom whose annual production exceeds 26,000 tons. The method of treatment adopted is very similar to that used for menhaden, except that the material, before being cooked, is reduced to a uniform size by means of a rotary cutter, and the superfluous water is removed by means of centrifugal machines.

Large quantities of fish scrap are also made from herring in the United Kingdom and in Norway both from the whole fish and also from the waste resulting from kippering and salting herring.

TABLE 58

PRODUCTION OF SCRAP FROM MISCELLANEOUS FISH IN 1922

	Dried Scrap		Crude or Green Scrap	
	Quantity	Value	Quantity	Value
Massachusetts and Maine............	3,455 Tons	$ 146,103	390 Tons	$9,175
Maryland............................	1,230 "	28,970	...	.....
New York, Virginia, North Carolina, and Florida	1,593 "	52,521	...	.....
Washington, Oregon, California, and Alaska..........................	15,354 "	862,752	...	.....
Total..............................	21,638 "	$1,090,346	390 "	$9,175

Considerable quantities of manure are produced in Norway from the wastes resulting from the dressing of cod. As the fish contains but little oil, it is not cooked but is chopped into small pieces and dried, first in the open air, and finally in kilns. The product, which on leaving the kilns contains about 12 per cent of moisture, is finely ground between millstones.

A limited amount of fertilizer and oil has been prepared from dogfish. The chief centers of this industry were at Canso and Clark's Harbor in Nova Scotia, and at Shippigan, New Brunswick. Some scrap is also manufactured from dogfish on the Pacific Coast of the United States.

In Japan, very large quantities of fertilizer are prepared from herring. The product, called "nishinkasu," is made by first boiling and then pressing the fish. The cake produced is broken up and dried in the sun on bamboo or reed screens. Much fertilizer is also prepared from sardines. The fish fertilizer produced annually in Japan is valued at over a million and a half dollars.

Methods of Manufacture.

Oriental Methods.—In Siberia, Japan, China, and India crude methods of sun drying fish are often used for the preparation of scrap. Non-fatty fish are not cooked but simply spread out to dry in the sun. Fatty fish are boiled with water, the oil is skimmed off, the fish are pressed slightly by some means or other, and the cooked residue is spread in the sun, either on trays or mats or on the grass. Figure 161 shows the drying of fish scrap on the grass in Siberia.

The modern method of manufacturing fish scrap does not differ in principle from the latter procedure. Modern machinery eliminates most of the labor and by a rapid handling of the material produces a better quality of scrap.

The Preparation of Menhaden Scrap.

Dried Scrap.—The handling, steam-cooking and pressing of menhaden fish and sardine, tuna, and salmon waste in the modern American factories have been described in Chapter 21 on pages 421 to 437. A small amount of the pressed scrap called green scrap is sold without undergoing further treatment to farmers in the neighborhood of the factories. The remainder is either acidulated with sulphuric acid or dried either with hot air or steam.

The hot-air drier has been almost universally adopted for the production of dried menhaden scrap. The operation of the type of direct-heat drier generally used for the drying of the pressed menhaden has been described by Geer:[1]

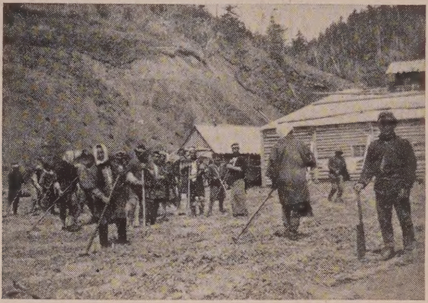

FIG. 161.—Drying fish scrap on an open field in Siberia.

> The pressed fish remains on the floor of the room below the pressroom, where it is deposited after leaving the presses, until the following morning, when it is shoveled to a conveyor, usually of the chain type with wood flights placed at intervals of about 2 feet, and carried to the hopper of the drier. The drier is generally set under a shed built apart from the main factory building as a precaution against setting fire to the building should the intense heat in the drier fire the scrap. The direct-heat rotary drier is a revolving cylindrical iron or steel shell of various sizes, through which hot furnace gases pass, generally under forced draft produced by a fan at the side of the furnace. The cylinder has 12 spiral flights or shelves, each 8 inches wide, attached to its inner surface and running the entire length; these add to the rigidity of the cylinder and also lift the scrap to the highest point of the rotation and shower it through the hot furnace gases. The wet scrap and the gases enter the cylinder at the same end. . . . The cylinder is encircled by two steel tires, which are securely fastened to it, each resting on a set of four steel rollers, which in turn rest on brick foundations.
>
> The power for rotating the drier is imparted first to these rollers by means of a shaft and from them by friction to the tires, or by the use of a spur pinion meshing with a large spur-gear ring encircling the drier. The brick furnace, which is provided with an automatic stoker, consumes about 5 tons of coal a day; its size is 9 by 10 feet, and it is built about the front or feed end of the drier, which is set about 9 inches higher at this point than at the other end, so that the trend of the scrap will be toward the lower and discharge end, assisted, of course, by the forced draft which blows it through as the flights referred to above lift it as the cylinder revolves. The lower end enters a brick chimney-like chamber 8 feet wide by 12 feet long; this serves as an outlet for the hot air and the vapor and also as a settling chamber for the dust coming from the dried scrap. . . . It is necessary to give close attention during the operation of the hot-air drier in order to guard against burning the scrap by having too much heat and also to keep heat enough to dry it thoroughly. It is sometimes necessary to run it through the second time if the first passage is too rapid. The scrap dried by this process is much darker in color than that dried on

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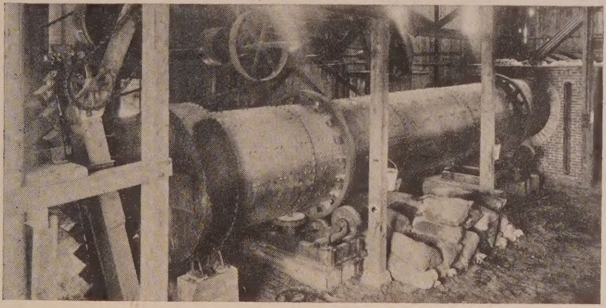
[1] *Bureau Fisheries, Rept.* 1914, Appendix 3; also Doc. 811 (1917).

platforms, no doubt because it is somewhat scorched by the intense heat of the furnace.

The scrap drops from the drier into a screw conveyor, which passes through the wall of the chimney, and is taken up by a chain conveyor to be carried to the scrap room. The box in which this conveyor moves is usually placed close under the roof of the building and is provided with traps or slides which may be drawn and the scrap deposited in any part of the room desired. Twelve thousand to fifteen thousand fish will make 1 ton of scrap; the quantity made from one million fish varies from 75 to 85 tons.

A direct-heat rotary blast drier such as that described by Geer is shown in Fig. 162.

The temperature and the rate of passage of the scrap through the drier is regulated so that the moisture content of the scrap is reduced to approximately 8 or 10 per cent. When desiccated to this point, decomposition is prevented and the material can be kept without molding or without loss of ammonia and can readily be ground to a powder.



Courtesy Ruggles-Coles Engineering Co.

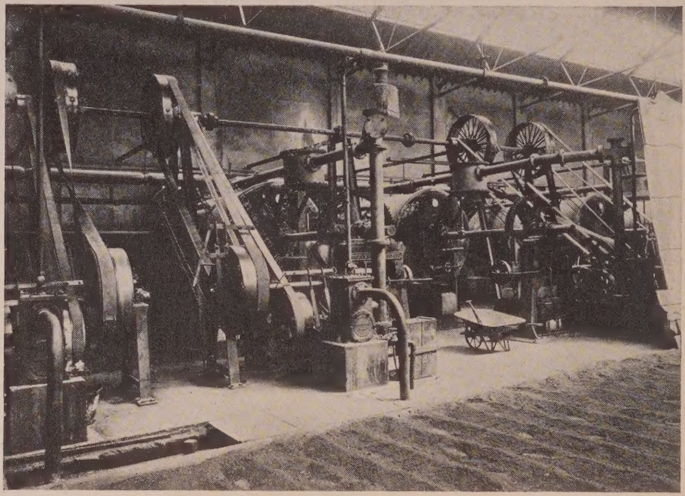
FIG. 162.—A direct-heat rotary drier for fish scrap.

Menhaden scrap, dried in direct-heat rotary driers, is utilized either as animal feed or as fertilizer. The bulk of it is purchased by the manufacturers of mixed fertilizers. Fish scrap is occasionally shipped in bulk, being transferred by a conveyor directly to the hold of the transporting vessel. Much is bagged without further treatment; some is ground before bagging.

Acidulated Scrap.—In 1921, approximately 40 per cent of the total output of menhaden scrap was not dried but was acidulated with sulphuric acid. Pressed scrap, although it is discharged from the continuous screw press in the form of a hard and apparently dry cake, still contains 45 to 50 per cent of moisture and if shipped in this condition soon decomposes. An Englishman, Petitt, about the year 1850, patented a process of preserving fish for use as fertilizer by means of the addition of sulphuric or hydrochloric acid. Petitt found that the addition of relatively small amounts of acids prevented bacterial decomposition of fish. The addition of acid not only preserves the fish scrap but attacks the bones and converts a portion of the tricalcium phosphate into the more readily available forms of the acid phosphates.

The acid is usually applied at the rate of 35 to 55 pounds per thousand pounds of scrap as the pressed fish is being conveyed to the shed in which the acidulated scrap is stored. It is either sprayed over the scrap as it flows from a lead lined tank, or is poured from a dipper by a man standing near the conveyor box.

This process eliminates the expensive and disagreeable drying, which is an important factor in certain localities, as the hot air drier is always a foul smelling machine, and is the cause of much contention among the residents in the neighborhood of the factory.



Courtesy Ernest Scott and Co., Ltd.

Fig. 163.—Five units of a seven-unit drier installation handling 10 tons of fish hourly.

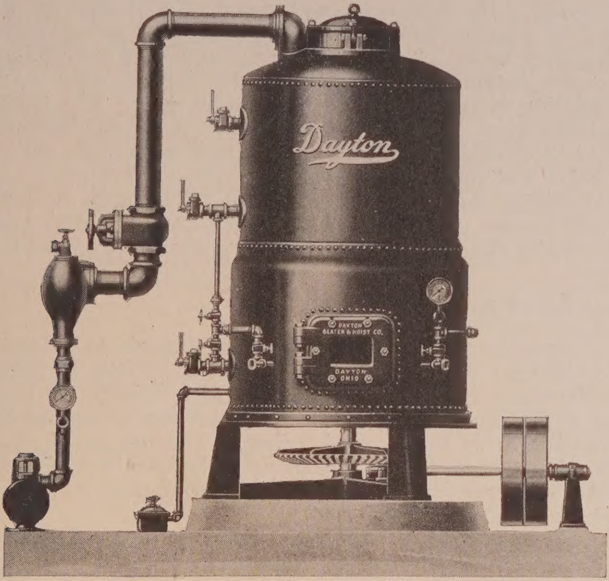
If the scrap is to be shipped for any considerable distance, the presence of such a large amount of water (45-50%) is a decided disadvantage as it nearly doubles the cost of shipping a given weight of fertilizer material. Also, because of this high moisture content, it cannot be mixed with many other fertilizer materials. If there is but slight demand for the acidulated scrap, it may be dried at a later date.

Manufacture of Scrap from Other Fish.

Salmon Scrap.—No single type of drier has been adopted by the salmon by-products industries. Several direct-heat driers resembling those in use in the menhaden scrap industry are in use. The old batch style steam jacketed cylinder having moving arms to agitate the scrap is still used, although it is not regarded as being satisfactory. An improvement of this type has a condenser attached and operates under vacuum.

A new type, which is said to be very efficient, consists of a cylinder jacketed sectionally, equipped with agitator arms which move the scrap at a given speed, a set of steam coils and a fan which supply heated air. The fan draws the heated air from the coils in the reverse direction to the motion of the scrap in the cylinder. The sectional jacketing permits a varying heat to be applied along the line of travel of the scrap.

Extraction Process.—The extraction process, which has been described in Chapter 21, is used chiefly for the preparation of fish meal from sardine waste. Extracted scrap is somewhat better than pressed scrap for fertilizing purposes, as nearly all of the oil, which many persons consider objectionable as a component of fertilizer, has been removed in the extraction process. The composition of extracted sardine scrap is given on page 472.



Courtesy Dayton Beater and Hoist Co.

Fig. 164.—The Dayton rendering tank, a combination of a cooker and drier.

Special Apparatus.

Special types of equipment are occasionally used for the handling of relatively small amounts of fish waste.

The "Dayton" type rendering tank is a comparatively low priced apparatus combining in one piece of apparatus a cooker and drier. As no press is used in preparing fish meal by this process, this method is applicable chiefly to non-fatty fish. The "Dayton" tank, shown in Fig. 164, is loaded from the top and then closed, remaining so until the process is completed. Steam is introduced into the cooking chamber in such a manner that the stock is thoroughly cooked from all points. As the stock rests upon the perforated diaphragm, steam penetrates from below as well as from the top and sides, insuring a thorough saturation of the stock. During the cooking process, the tank water, condensed steam and the oils drain through to the bottom of the tank where they are carried off. Towards the end of the period, steam is turned off at all points except the top, so that the pressure on the upper surface will compress the stock, forcing out all excess moisture.

The drying of the stock is accomplished by first shutting off the steam in the cooking chamber and sending it into the steam jackets surrounding the drying chamber below. The tank is equipped with two agitators, one resting on the bottom of the drying chamber and the other on the perforated diaphragm, and both keyed to a central shaft. The action of the upper agitator breaks up the stock and forces it through the diaphragm to the hot bottom of the tank, where it is in turn taken up by the revolving agitator below and slowly turned over and over. The result is a uniform and rapid drying, the vapors being carried off through the top of the tank by the vacuum pump. All objectionable odors are eliminated, since the tank remains closed at all times and no vapors are permitted to escape.

Composition of Scrap.

The composition of the finished product depends to a large extent upon the character of the raw material and the process of preparation. Excessive amounts of oils are objectionable in fertilizers, for in addition to having no fertilizer value they counteract to some extent the beneficial results obtained from the use of fish scrap. The amount of oil in menhaden or salmon scrap depends chiefly upon the efficiency of the presses used. Thorough pressing pays, for not only is the quality of the product improved but valuable oil is obtained.

A number of analyses of fish scrap fertilizers prepared from various materials are presented in Table 59.

TABLE 59

ANALYSES OF FISH FERTILIZERS PREPARED FROM VARIOUS MATERIALS

Raw Material	No. of Samples Analyzed	Moisture (H_2O)	Nitrogen (N)	Phosphoric Acid (P_2O_5)	Fat *	Analyst
Menhaden	10	7.72	8.43	6.69	6.99	Parker and Lindemuth
Sardine waste	1	5.57	7.97	7.11	8.42	Lindemuth
Salmon waste	5	5.17	8.70	8.31	14.32	Lindemuth
Tuna waste	1	4.21	8.54	7.25	13.27	Lindemuth
Dogfish	1	6.35	12.15	3.59	7.89	Lindemuth
Cod heads	1	3.5	6.5	20.0	...	....
Cod waste	1	13.0	8.0	14.9	...	....

* More accurately ether extract. This consists principally of oils.

Availability.

From the data presented in Table 59 it is seen that the average nitrogen content of fish scrap is about 8.5 per cent indicating the presence of about 53.1 per cent of protein. This protein quickly undergoes decomposition when the fertilizer is applied to the soil, the nitrogen being readily available. By most writers, fish scrap is ranked next to dried blood as an organic source of nitrogen for plants. If the rate of availability of sodium nitrate is considered as 100, dried blood may be ranked at 70 and fish scrap at 65.

The amount of phosphoric acid in fish scrap is more variable than its nitrogen content, but usually is in the neighborhood of 7 per cent. The phosphoric acid in acidulated scrap is said to be more readily available than that of the dried scrap. The sulphuric acid attacks part of the tricalcium phosphate of the fish bones converting it into the more readily available monocalcium phosphate. The following percentage figures[2] indicate the condition of the phosphoric acid in ordinary dry scrap and in the wet and dried forms of acidulated scrap:

TABLE 60

FORM OF PHOSPHORIC ACID IN FISH SCRAP

	Acidulated Scrap		Dry Scrap
	Wet	Dry	
Water soluble phosphoric acid	1.17	0.55	0.44 to 0.66
Citrate soluble phosphoric acid	1.13	2.64	3.1 to 5.14
Insoluble phosphoric acid	2.58	5.06	1.7 to 3.3
Water in scrap	45.4	12.5	About 12

These figures seem to indicate that, if acidulated scrap is dried, a large proportion of the monocalcium phosphate (water soluble) formed during the acidulation reverts to the dicalcium phosphate (citrate soluble) and tricalcium phosphate (insoluble) forms.

The organic matter, which serves as a carrier for the nitrogen and phosphoric acid in scrap, is of considerable value, for it acts in the same beneficial way as the organic matter in farm and green manures.

Although the analyses of fish scrap given in Table 59 do not indicate any potash, the average K_2O content of fish scrap is about 0.5%. This becomes available when the fertilizer rots.

Fish scrap has met with great success as a fertilizer and now constitutes one of the important sources of organic nitrogen. Its use is familiar to all fertilizer dealers and to most farmers who use unmixed fertilizers.

A limited quantity of fish scrap is used directly as a fertilizer without admixture with other fertilizer ingredients. It may be used to advantage on crops whose period of growth is prolonged during the season, since it furnishes a gradual supply of nitrate nitrogen as it undergoes decomposition and nitrification. As fish scrap is high in nitrogen and very low in potash, great care must be used in applying it without supplementing with adequate amounts of potash and phosphoric acid. On soils rich in potash, but low in nitrogen, its use, unmixed with other materials, may be recommended for certain crops. It should be applied early in the year when the land is first worked, and should be immediately worked into the land, otherwise it will be eaten by birds.

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[2] *Bull. Imperial Institute, 12* (1914), 440.

In general, more satisfactory results have been obtained by mixing it with other fertilizer ingredients in certain proportions to fulfill the requirements of a given crop on a soil of known composition.

In recent years, many farmers have mixed their own fertilizers according to formulas which they consider best for their crops and soil. Fish scrap is a popular constituent of these home mixtures as the value of fish meal as a fertilizing material has long been known. Fish scrap may be mixed with any of the ordinary fertilizer components without objectionable results with the following exceptions: Calcium oxide (quicklime), calcium hydroxide (slaked lime), potassium carbonate (in wood ashes), basic slag phosphate, calcium cyanamid, and basic calcium nitrate.

Large quantities are mixed with other fertilizer components by the manufacturers of the scrap to form the so-called complete fertilizers and are sold, generally locally, under brand names.

The larger proportion of the scrap is sold through brokers to the larger manufacturers of fertilizers by whom it is mixed and marketed.

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Chapter 24.

Fish Meal.

The Industry.

While the fish meal industry is one of the novel industries of America, the feeding of fish and fish scrap to animals is by no means new. As early as 1833, cattle at Provincetown, Massachusetts, were fed upon fish. And in 1864, the feeding of pressed herring scrap was recommended by Dana of Maine, and feeding trials with menhaden scrap were suggested.

The scarcity and high price of stock feeds during and immediately after the World War forced the farmers of America to utilize materials as feeds which had heretofore been neglected. The value of fish meal as an animal feed had previously been generally recognized, but, partly on account of prejudice and partly because of custom, the stock feeders had been slow to use it.

In recent years, the use of fish meal as a stock and poultry food has grown rapidly. No accurate statistics are available for any given year, but, in 1921, it has been estimated that of the total production of 107,273 tons of fish scrap in the United States, 25,000 tons were fish meal. In 1922 it was reported that 7,172 tons of menhaden scrap valued at $390,677 were sold as fish meal.

The by-products factories of the Pacific Coast have been quicker to manufacture scrap especially for meal than those of the Atlantic Coast. Doubtless this may be accounted for in the difference in the size of the factories on the two coasts, and the recent development of the industry in the west. Several factories have been built on the Pacific Coast with equipment especially designed for the manufacture of fish meal. Many menhaden scrap and oil factories in the east have offered their best grade of dried scrap as meal, but have refused to install the driers necessary for the manufacture of the best grade of meal.

In the United Kingdom, the chief raw material is the offal from fish salting plants and fishmongers. The annual production of fish meal in Great Britain is over 18,000 tons. Before the war practically all of it was exported to Germany, but during the war, when exportation practically ceased, the British farmers learned to use it, and now a considerable proportion of the annual production is fed to stock in England.

Much fish meal is prepared in Norway from cod and herring waste and sardines. A large proportion of this is exported to Germany where fish meal is a popular feeding stuff.

Fish scrap is also used as an animal feed in Japan where it is prepared in large quantities. Some meal is prepared in Siberia, where modern methods of manufacture have recently been introduced.

Methods of Manufacture.

Press Method.—The manufacture of fish oil and green scrap by cooking fish and fish waste with steam, and pressing in either curbs and hydraulic presses or in the continuous screw presses, has been described in Chapter 21 on pages 421 to 437. The chief difference between the methods of manufacture of fish scrap for fertilizer and for meal is that the latter is to be used as a stock food and should therefore be prepared from perfectly fresh raw material in a clean sanitary factory and carefully dried without scorching.

In the menhaden meal industry, the automatic continuous cooker and continuous screw presses previously described are commonly used in the preparation of the green scrap. In the preparation of meal, the fish is pressed while hot to insure the removal of the maximum quantity of the oil.

The pressed fish must be carefully dried. In the menhaden factories, rotary hot air driers, such as those described in Chapter 23 on page 458, are commonly used although there is some danger of scorching the fish. This danger is eliminated by the use of the steam-heated rotary driers.

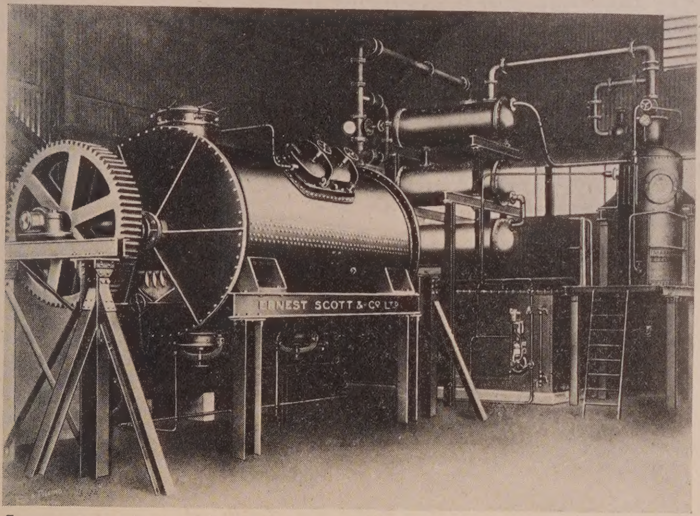
These rotary driers are of two general types. In one, the furnace of the direct-heat drier is replaced by a number of steam coils and a fan blower. This blower forces a constant stream of air over the steam coils and into the revolving drying cylinder. The damp material enters the revolving cylinder at the higher end through a suitable feed chute, falls to the bottom of the drum, is picked up by the longitudinal lifters, elevated to nearly the highest point and then showered through the stream of heated air. Both the counter-current and the parallel-current types are employed depending upon the characteristics of the material to be dried.

The other type of steam drier consists also of a slightly inclined revolving steel cylinder, but, in this drier, the steam tubes are placed inside the cylinder. These tubes are arranged in the form of a ring around the inside of the cylinder, and revolve with the cylinder. These tubes communicate directly with a cylindrical drum at one end of the machine through which the steam for drying is admitted to the tubes, and the condensation water removed from same by a suitable steam trap. Numerous radial shelves, running the entire length of the cylinder, serve to shower the wet material over the heated steam tubes and also to aid in moving the dried material toward the discharge end, where it leaves the machine through suitable openings in the steel shell. A large vapor flue, placed at the feed end of the machine, draws off the water vapor liberated from the wet material during its passage through the drier.

The general types of driers in common use in the salmon meal industry have been described on pages 460 and 461.

Extraction Process.—The details of the extraction process as applied in the production of sardine meal have already been considered in Chapter 21 on page 432. Although the fish are always somewhat scorched by cooking with direct heat in this process, since the meal produced contains only 3 per cent of oil it is preferred to the pressed scrap as feed for poultry.

After cooking, drying and extracting the sardine waste little remains to be done in order to prepare the product for the market. Upon removal from the extraction tank, the meal is screened or sifted to remove any of the larger pieces of fish which have not been broken up. The screenings consist of pieces of backbone, bones of the skull, especially the cheekplates or opercles and a few chunks of meal which remain packed or were burned somewhat in the drier. These tailings are either ground or run through the drier again. After screening, if the meal is dry enough, it is sacked. If it contains more than 10 per cent of moisture it is run through the drier again.



Courtesy Ernest Scott and Co., Ltd.

Fig. 165.—Solvent oil extraction plant. In this apparatus the solvent is introduced in vapor form which evaporates the water contained in the fish and at the same time dissolves the oil. The oily saturated solvent is removed to the spent solvent tank and thence to a still.

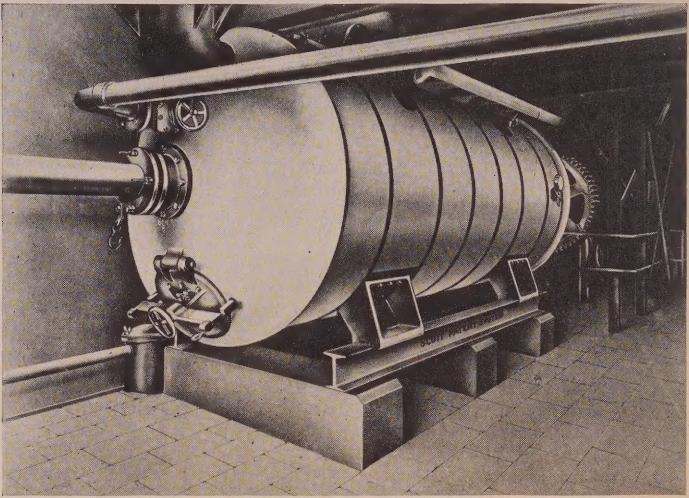
The average analysis of scrap prepared by this process is given on page 472.

For chicken feed a granular form such as that produced by the use of the rotary driers may be used without further grinding provided no large fish have been used in its preparation. For other purposes it is necessary to grind the dried material to a fairly fine meal.

Vacuum Method.—The vacuum processes have the advantages of manufacturing fish meal at a lower temperature, and therefore of better color, and of eliminating the obnoxious odors commonly associated with the making of fish scrap. This type is particularly advantageous in dealing with non-oily fish as such fish can be converted into meal in a single operation without creating any disagreeable odors.

In the vacuum drier shown in Fig. 166, the whole non-oily fish or waste are charged through a large charging hole in the upper portion of the vessel. The drier is steam-jacketed and provided with a central shaft to which are fixed stirrer blades which almost touch the sides and prevent any baking of the fish meal on the inner walls of the shell. The blades of the stirrer are set at an angle so as not only to turn the meal over, but also to propel the meal through the drier and prevent packing at any one point.

The whole apparatus is under a vacuum which is created by a suitable vacuum pump. The water vapor evaporated in the drier is condensed before passing to the vacuum pump. Any other vapors remaining uncondensed pass to the under side of the steam boiler fire and are consumed and pass off mixed with the other products of combustion.



Courtesy Ernest Scott and Co., Ltd.

FIG. 166.—Vacuum drier for fish scrap.

Special Continuous Processes.—In addition to the vacuum process, there are two other important novel processes designed especially for the manufacture of fish meal.

The California Press Manufacturing Company's fish meal plant is a continuous steam cooking, pressing, and hot air drying process. While the apparatus is designed primarily for the production of fish meal, oil is recovered, if waste from fatty fish is used, by separating in settling tanks the oil and water pressed from the cooked fish. A ribbon conveyor moves the fish waste through the cooker, which is provided with a number of jets of live steam. Ledges are placed on the conveyor upon which the material lodges, and the steam jets are arranged to play upon each ledge.

From the steam cooker, the fish waste passes by means of a screw conveyor into a continuous screw press. This consists of two rotary screws coördinated within a foraminated casing. In the press the material is subjected to a gradually augmented pressure. From the press, the material passes to the drier drums in which the material is tumbled. Air drawn by a fan between heated walls of a furnace is blown through the rotating drier drums. After emerging from the drier, the material is cooled in currents of cold air and is then sacked.

As may be seen from the above description, the operations in the preparation of fish meal by this process are the same as those used in the manufacture of menhaden scrap according to the usual process employed on the Atlantic seaboard. The advantages of the use of the California Press Manufacturing Company's outfit for fish waste is that it is designed primarily for relatively small amounts of material and it is compactly built and therefore does not require the floor space nor the labor necessary for the fish scrap equipment composed of separate units.

The firm of Stanley Hiller, Incorporated, have recently offered a compact fish meal reduction unit designed to handle about three tons of fish or fish waste per hour. This plant is especially adapted to handle waste from a fish cannery. The process, like that of the California Press Manufacturing Company, is of the continuous type.

The material fed in by a conveyor is cut up with a special cutter contained in the hopper, which chops the fish to a uniform size. The cut fish is then conveyed to the continuous pressure cooker where a constant presure can be maintained by the adjustment of the reducing valve. The cooked material passes through a continuous screw press, thence into the drier which is of the rotary double drum concurrent type, the heat being supplied by oil burners. The dried meal is conveyed to the grinder and then into a hopper ready for sacking.

If fatty fish or waste are being reduced, the oil and water emulsion expressed by the screw press is run into settling tanks where it is separated.

Being carefully and compactly constructed this plant can be operated at a low cost.

Comparative Efficiency of Fish Meal Plants.—Dill[1] has studied recently the efficiency of operation of the two types of fish meal plants used in the production of tuna fish meal in Southern California. One type was the continuous process and consisted of a cooker, press and drier of modern design. The other type of plant is in use in only a few canneries and consists of a wooden hopper, an hydraulic press and two steam-jacketed cylindrical driers. The latter outfit is sometimes called the "batch" type of reduction plant.

Dill concludes that, since the fish meal output during the tuna season does not commonly exceed 200 tons for any one cannery, the investment required is a most important factor. The limiting factor in the capacity of the continuous plant is the drier. It is sometimes overloaded, with the immediate consequence of leaving too much moisture in the meal. If the temperature is then increased, scorching and possibly a fire results.

Moreover, he finds, that as operated at present in the manufacture

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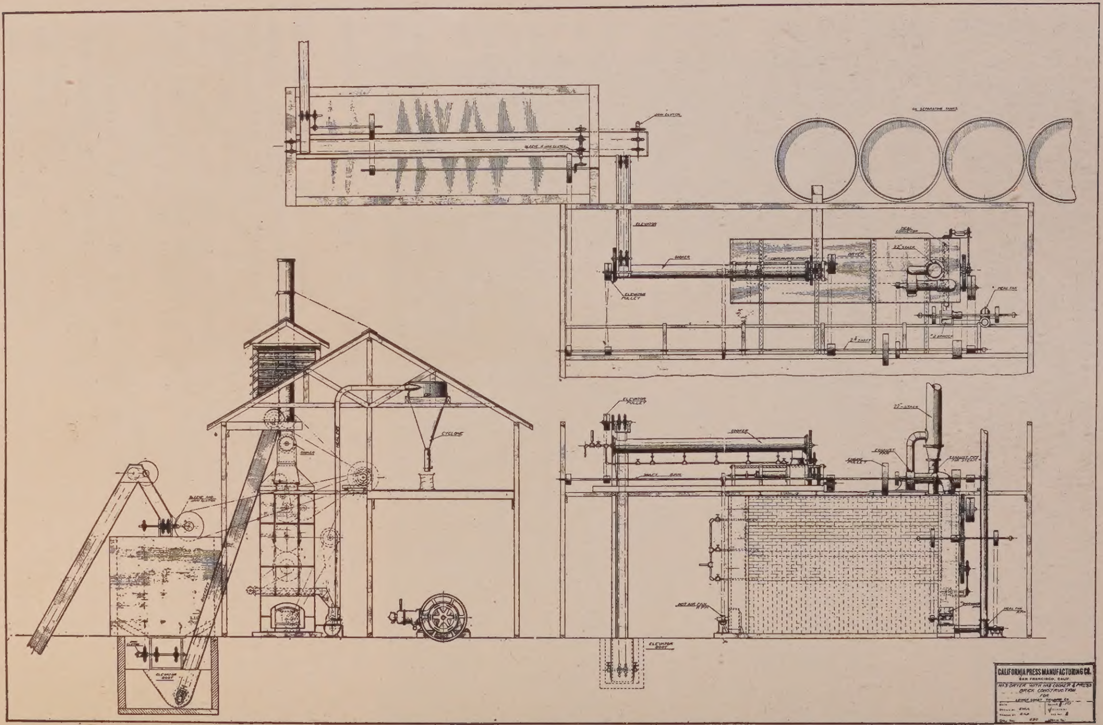
[1] *American Fertilizer*, *58* (1923), No. 7, 25-8.



Courtesy California Press Manufacturing Co.

FIG. 167.—Diagram showing arrangement of the California Press Manufacturing Company's fish meal plant.

of tuna fish meal, the continuous plant loses almost three times as much nitrogen per unit of fish meal as the "batch" or "hydraulic" plant, and that the composition of the fish meal gives little or no clue as far as nitrogen conservation during the process of manufacture is concerned.

The merit of the continuous plant lies in its labor-saving advantages. It can be operated by a foreman and two laborers, while a foreman and five laborers were employed by the hydraulic plant.

Insufficient researches have been carried out to indicate conclusively the relative merits of the various machines offered. Evidently many continuous fish meal plants are not operated to best advantage. Their operators should be trained to understand the optimum mode of operation.

Storage.

Since fish meal is fed to animals it should be stored in a dry place so that it will not mold. If the meal is improperly dried, it may become wormy as well as moldy. If the moisture content of the meal is above 15 per cent, spontaneous combustion is likely to take place at any time because of the heating of the meal caused by bacterial decomposition.

Composition.

The composition of fish meals depends upon the nature of the raw material and the process used in its manufacture. Feed made from non-fatty fish waste, such as that from cod, haddock, hake, cusk and pollack, naturally contains little fat. Meal prepared from waste composed of heads, bones, tails and fins usually contains relatively high amounts of phosphates. The content of fat and moisture depends, not only upon the nature of the waste used, but also upon the efficiency of the press and upon the extent of the drying.

For these reasons, the composition of fish meal is extremely variable. It should therefore be purchased only on the basis of its analysis. Formerly, it was thought that fish meals containing the lowest percentages of fat were the best. If the fat is rancid, this is undoubtedly true; but, since fresh fat is easily digestible, has a definite food value, and may be fed without imparting a taint to the final product (meat, milk or eggs), high grade meals should not be judged on this basis. Herring meal prepared from sardine waste containing as much as 14.56 per cent of fat has been fed to chickens and cattle without imparting any flavor or taint to the eggs or milk. If the meal has been carefully prepared from fresh fish or fish waste and properly stored, the fat as well as the protein content may be considered of nutrient value.

Representative analyses of various fish meals are given below:

Menhaden.—The nitrogen content of menhaden meal varies from about 7.7 per cent to about 9.3 per cent, depending chiefly upon the moisture and fat content; as a rule, the lower the moisture and fat, the higher the percentage of nitrogen and calcium phosphate contained in the meal. Usually, the oil content varies between 5 and 8.5 per cent. The moisture content should not be above 10 per cent and is usually about 7 per cent. While the calcium phosphate of menhaden meal is of value as bone forming material for growing stock, the meal is not sold on the basis of its content which usually is about 15 per cent.

Sardine.—The following average analyses by Scofield[2] are of meals prepared from the waste of the sardine canneries of Southern California:

	Pressed scrap Per cent	Extracted scrap Per cent
Moisture	9–12	10
Nitrogen	9–10	10
Phosphoric acid	5–10	7–8
Fat (ether extract)	8–10	3

Salmon.—Lindemuth's[3] analyses of various samples of scrap prepared from salmon cuttings are given below:

TABLE 61

ANALYSES OF SALMON SCRAP

Location of Factory	Description	Moisture	Nitrogen	Phosphoric Acid	Oils *
		Per Cent	Per Cent	Per Cent	Per Cent
Klawack, Alaska...	Sample from trial run with steam drier....	5.36	9.39	5.32	14.96
Anacortes, Wash...	Dry scrap from steam drier...............	5.21	8.26	7.91	17.36
Anacortes, Wash...	Dry scrap from hot air drier...............	5.26	9.49	9.26	8.32
Seattle, Wash......	Dry scrap from steam drier...............	3.91	8.76	7.00	20.02
Astoria, Ore.......	Dry scrap from hot air drier...............	5.11	7.63	12.08	10.96

* More accurately ether extract.

These data seem to indicate that salmon scrap, as it is ordinarily prepared, is much higher in fat but lower in moisture than menhaden or sardine meal.

European Meals.—The analyses of various fish meals prepared in Europe are presented in Table 62.

Nutritive Value.

Probably the first feeding tests with fish meal were made in 1873 and 1874 by Weiske[4] and were reported in 1875 and 1876 by Kellner, Schrodt and Wimmer.[5] These investigators concluded that the protein of fish meal was digested by sheep as well as, or better than, that from vegetable sources. From 77 to 83 per cent of the protein was found to have been

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[2] *Cal. Fish and Game, 7* (1921), 207-217.

[3] *J. Ind. Eng. Chem., 7* (1915), 616.

[4] *Wochenbl. d. landw. Ver. i- Grossherzogtum Baden,* 1874, 318.

[5] *J. f. Landw., 24,* 1876, 265-297.

TABLE 62

EUROPEAN FISH MEALS

Scrap	Phosphoric Acid (P_2O_5)	Nitrogen	Protein (N × 6.25)	Ether Extract (Fat)
	Per Cent	Per Cent	Per Cent	Per Cent
Norwegian cod meal	10.9 to 12.8	8.0 to 9.6	50 to 60	1 to 2
Herring meal	3.6 to 4.6	9.6 to 11.2	60 to 70	10 to 12
English waste meal	6.4 to 8.2	8.8 to 10.4	55 to 65	3 to 6
German meal	....	9.57	59.8	2.53
Scotch meal	5.84	8.57	53.6	14.9
English meal	5.20	11.83	73.9	....

digested. In a later experiment, Kellner[6] found that sheep digested as much as 90 per cent of the protein, 76.4 per cent of the fat, and 15 per cent of the ash.

Lehman[7] determined the digestibility of the protein of fish meal with pepsin and pancreatic extract and found that 98.6 per cent was digested.

In 1894 Kühn-Cornieten[8] conducted a practical test with six cows, comparing the yield and quality of milk and butter when the cows were fed a ration containing no fish meal with the results obtained when fish meal was substituted for dried malt husks and sunflower meal in the basal ration. From 1⅓ to 2⅓ pounds of German fish meal were fed per head per day in the different trials. The butter did not have a fishy odor or taste. Since the quantity of milk was about the same, the percentage of fat higher, and the feed cheaper, he concluded that fish meal was a valuable feeding stuff.

Schenke,[9] in 1903, carried out an extensive investigation of the nutritive value of fish meal. He showed that the protein consists mainly of meat fibrin, albumen, and gelatinous substances. The ash consists largely of sodium, potassium, and calcium phosphates, and sodium, magnesium, and potassium chlorides. After reviewing all the work of the German experiment stations and of various other investigators, he concludes that fish meal is a valuable supplementary food for animals, when it is fed with other foods low in protein; that its fat and protein are easily digested and that it imparted no objectionable flavor to milk and butter when used supplementary in rations for dairy cows.

Weber[10] has made a thorough study of the possibilities of the manufacture of meal from the waste from the Maine sardine industry and of the value of sardine meal. After reviewing the extensive literature on the nutritive properties of fish meal and the analyses and feeding experiments of the U. S. Department of Agriculture, he concludes:

> Laboratory tests have shown that the coefficients of digestibility of the principal constituents of fish meal—the protein and fat—are high, and the feeding experiments

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[6] *Landw. Vers. Sta.*, *20* (1877), 423.

[7] *Landw. Wochembl. Schleswig. Holstein*, 1892, No. 23, 200-201.

[8] *Molkerei Zeitung*, *8* (1894), 675.

[9] *Landw. Vers. Sta.*, *58* (1903), 55-64. See also Die Futtermittel des Handels, Berlin.

[10] *U. S. Dept. Agr., Bull.* 378 (1916).

> have all shown it to be as valuable as many other high-protein concentrates with which it has been compared.
>
> From the feeding experiments it appears that there has not been just cause for the assumption that the feeding of fish meal of good quality imparts a fishy taint to such products as milk, butter, eggs, and meat. When the meal is fed in proper quantities, as a supplementary feed with other feeds, apparently no deleterious effects are noticeable in regard to taint or flavor of fish. There is a possibility that it may impart its flavor to the products of animals or fowls when it is fed to them in too large quantities. Even under these circumstances its use would be warranted, as the feeding of the meal can be discontinued a sufficient length of time during the final fattening period to eliminate any objectionable taint.

All the literature on this subject cannot be reviewed here, but it should be evident from the above summary that fish meal is a valuable protein concentrate, that the fat is easily digested, and that it may be used in place of meat meal and other feeds of high protein content with satisfactory results.

Use.

Fish meal is an excellent source of protein for poultry and for growing livestock as not only is the protein in a readily digestible form but the feed contains a high percentage of calcium phosphate which is needed for the formation of eggs and bones. However, large quantities of fish meal containing high percentages of fat should not be fed to poultry.

It must be remembered that fish meal is a highly concentrated protein food, and that large quantities should never be fed at one time. In general, the rules for the feeding of dried blood and tankage apply.

The following quantities[11] of fish meal have been suggested as the proper amounts to be given daily to the different kinds of stock:

Cattle—2 lb. for every 1,000 lb. live weight.

Pigs—¼ to ½ lb. according to weight.

Sheep—⅒ to ⅕ lb. for every 100 lb. live weight.

Poultry—Adult fowls should receive not more than 10 per cent and chickens not more than 5 per cent of their whole diet in **this** form. Fish meal with low percentages of oil and salt should be selected and the birds should be gradually accustomed to the food.

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[11] *J. Board Agr.* (Great Britain), *21* (1914), 688-94.

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Chapter 25.

Fish Glue and Isinglass.

The Manufacture and Properties of Fish Glue.

Importance and Location of the Industry.

The fish glue industry is one of the minor by-products industries. In 1922, five factories in the United States produced a total of 323,003 gallons. These factories are located in Gloucester and Boston, Massachusetts and San Francisco, California. Small amounts of glue are manufactured in Canada. In England, glue is made at many fish scrap factories from the water in which the fish have been cooked. Considerable qualities of glue are prepared in Norway and Japan. The great obstacle confronting the industry is the difficulty of obtaining a regular supply of suitable glue stock in sufficient quantities.

The Chemistry of Fish Glue Manufacture.

The conversion of animal hides and bones into gelatin and glue has been the subject of many researches; but little has been published concerning the preparation of fish gelatin and glue. The hydrolysis of fish sounds or air bladders most nearly resembles the manufacture of hide glue, for when the tissue is heated with water it dissolves and, upon evaporating and cooling the resultant solution, a gel is formed which is a gelatin of high purity. Upon hydrolysis, most other portions of fish yield glue solutions which do not gel at ordinary temperatures and are called liquid glues.

Comparatively little is known concerning the composition of fish skin, scales, and bones. However, it has been found that fish skin and bones contain much collagen and other proteins resembling collagen. The scales of fish contain much ichthylepidin in addition. Upon careful hydrolysis with steam or boiling water the collagen and related proteins yield gelatin and various proteoses. The percentage of true gelatin formed in the manufacture of fish glue is much smaller and that of proteoses is much higher than in the manufacture of hide glue. Since the proteoses are soluble in cold water whereas gelatin is not, fish glues are cold water soluble glues but hide glues merely swell in cold water and do not dissolve until the water is heated.

Source of Raw Materials.

Practically all of the fish glue manufactured today is made from the waste products of the cod, haddock, cusk, hake, and pollack fisheries.

These fish are the so-called "ground" fish which are caught chiefly on trawl lines and in otter trawl nets on the banks. Some species of fish other than those mentioned above are used in the manufacture of glue—indeed any fish might be used for the making of glue—but for certain practical and economical reasons other fish are seldom used. The quality of glue prepared from these ground fish is higher and the yield greater than that made from most other fish. Many species of fish have such thin skin and small bones and therefore yield such small quantities of glue that it is not economically practical to use them; examples of this type of fish are the herring, mackerel and menhaden. Moreover, these fish contain large quantities of fat, therefore a special procedure must be followed to remove the fat during the glue-making process. Many fish which would otherwise be used are not caught largely in any one locality and consequently the supply of fish waste at any particular point is not large enough to justify the establishment of a glue factory. Other fish are caught only for short seasons, which would cause the glue factories to be idle most of the year.

The ground fish waste ordinarily is divided into three general classes, viz: (1) fish heads; (2) waste from salted fish, strictly speaking salt fish trimmings and bones, but usually considered trimmings and bones from salted cod, cusk, hake, pollack, and haddock, and haddock and pollack skins; (3) skin stock usually considered only skin from salted cod and cusk. The fish heads are fresh stock and are obtained from the wharves where the ground fish are cleaned preparatory to salting or marketing. With the exception of the exported salt fish, most of the dried salted fish is trimmed and skinned before it is packed for shipment. Most of it is also boned. These skins, trimmings and bones constitute waste and skin glue stock. Cod and cusk skins are thicker and furnish larger amounts of a better grade of glue than pollack and haddock skins; cod and cusk heads are also more valuable as glue stock than pollack and haddock heads. Because of this the larger fish glue factories pay higher prices for cod and cusk skins and heads than for similar haddock and pollack stock; therefore many of the larger fish salters keep these two classes of glue stock separate.

Methods of Manufacture.

Skin Glue.

The glue stock, regardless of whether it is obtained from fresh fish or salted fish, must be freed from salt or freshened before being made into glue. It is ordinarily agitated in running water until a chloride analysis of the wash water indicates that practically all of the salt has been washed out. In the larger factories this is accomplished by placing the stock in a circular tank about 30 feet in diameter and 5 feet deep, covering it with water and rolling it with a heavy wooden truncated cone-shaped roller which revolves as it travels around the tank. Fig. 169 shows one of the washers used by the Russia Cement Company. These washers are efficient as the roller squeezes out a portion of the water in the stock as it rolls over it; the stock then takes up more water which is squeezed out on the following revolution of the roller. Unfortunately, the stock tends to collect at the center of the washers and from time to time it must be pitched from the center towards the outside. A small stream of water is run through the washers continually, and, at intervals, all of the water is withdrawn and the tanks are refilled with fresh water. The fish skin and waste stock being waste products of the salt-fish industry, contain a much greater percentage of salt than the fish heads and consequently more care must be used in freshening it than in freshening the fish head stock. The washing of the stock requires at least twelve hours and often much longer. The usual practice is to weigh the stock as it is received from the fish wharves and dump it into the washers. After distributing a weighed quantity uniformly in a washer, the stock is covered with water and the agitator (roller) is started. The washing is usually commenced during the afternoon and is continued until the following morning, when the percentage of chlorides in the wash water is determined; if the analysis indicates that little salt remains in the stock, the washing is discontinued and the water drained off.

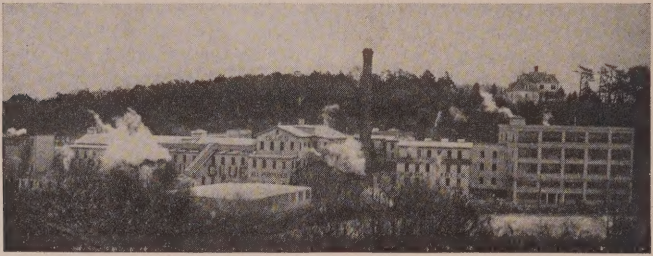

Courtesy Russia Cement Co.

FIG. 168.—The largest fish glue factory in the world, Gloucester, Mass.

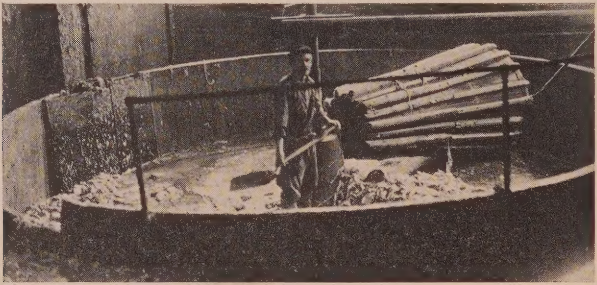
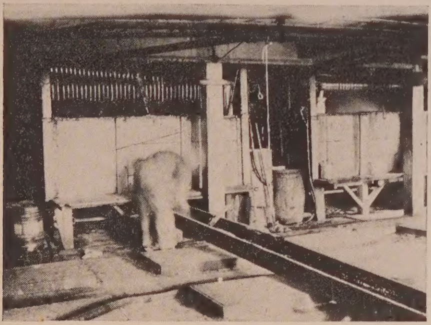

Courtesy Russia Cement Co.

FIG. 169.—Washer for fish glue stock.

The heavy roller disintegrates a portion of the stock which passes through the screen with the wash water. In order to prevent this loss, in some of the larger factories, the wash water is run into large settling tanks through which it slowly passes. This permits the major portion of the suspended matter to settle. The settlings are usually added to the chum or residue from the cooking which is then pressed, dried and sold as poultry food.

The freshened skin stock is pitched into the cookers which are usually situated adjacent to the washers. The usual type of cooker consists of a steam-jacketed, false-bottomed rectangular galvanized iron tank. These cookers are often about 12 feet long, 3 feet wide and 5 feet deep. A layer of excelsior is thrown on the false bottoms when the cookers are prepared for use and the stock is thrown in. A preservative is added at this stage to prevent the decomposition of the glue liquors during storage before evaporation. A small amount of acetic or other moderately strong acid is added to the stock; this acid acts as a catalytic agent and hastens the hydrolysis of the stock into glue. Moreover, it reduces the slime in the chum so that it may be pressed more readily and dried more easily.



Courtesy Russia Cement Co.

FIG. 170.—Copper coil evaporator for fish glue liquors.

The stock is covered with water; the steam is turned into the outer jacket and the cooking is continued for 6 to 10 hours. Then the glue liquor is drawn off and pumped to tanks and thence to the evaporators. The partially exhausted stock is again covered with water and cooked for a somewhat shorter period. Usually the skin stock is cooked but twice; the residue from the second cooking is commonly added to the freshened waste stock; thus no glue is lost.

The glue liquor is usually filtered through a mat of excelsior as it passes to the pump on its way to the tanks situated above the evaporators; and as the liquor flows into the evaporator it is often strained through muslin. These filtrations remove the greater proportion of suspended materials.

Many types of evaporators are in commercial use. The vacuum evaporators (shown in Fig. 27) are the most efficient type of glue liquor evaporators but are not in common use in the United States. Open pans heated with steam coils are used in many of the smaller fish glue factories.

One popular type of evaporator consists of a large revolving copper coil about 6 feet in diameter which revolves in a copper lined shallow wooden tank. Slightly superheated steam passing through the coil causes the glue liquor to evaporate rapidly on the surface of the coil as it is carried out of the body of the liquor as the coil revolves. This type of evaporator is illustrated in Fig. 170.

The evaporation is continued until the glue reaches the proper viscosity or body as it is commonly termed. This stage is determined by comparing the viscosity of a sample of the glue with that of a standard sample either in viscosity tubes or in a viscosimeter. A viscosimeter of the Stormer type is most satisfactory for the purpose. When the tests indicate that the proper viscosity has been reached, the additional preservatives and essential oils are added and the glue is drawn off ready to be tubed, bottled or canned.

Photo-Engraving Glue.—Only the very best grades of fish skin glue are satisfactory photo-engraving glues. The procedure followed in their manufacture differs but little from that outlined above for the regular fish glue. Much smaller amounts of essential oils and preservatives are used for its preservation, therefore photo-engraving glue as it is ordinarily prepared will not keep indefinitely as will the various grades of fish glue prepared for joining work. Only the first run of the best quality of fish-skin glue stock is taken. Care is used to prevent the admixture of stock or glue containing any considerable amount of grease, as grease and oil cause spots on the photo-engraving half-tone plates. Moreover, greater care must be used to insure a uniform admixture of the essential oil in the glue, as improper mixing causes some of the bottles of glue to be of poor quality because of an excess of oil. Photo-engraving glue also is clarified by a special settling process before it is bottled. Even with the greatest care in the manufacture, each batch of glue must be tested very carefully to determine whether or not it is suitable for the delicate work for which it is intended.

Waste Glue.

Waste glue, as has been previously explained, is prepared from salted ground fish trimmings and bones and haddock, hake, and pollack skins. This stock is washed and converted into glue in practically the same manner as that used in the preparation of fish skin glue. The same type of washers, which has already been described, is used. The cooking is accomplished in the galvanized iron jacketed cookers, although direct steam cookers are occasionally used. More acid is used for the conversion; the amount used depends somewhat upon the proportion of the bones in the stock, the more bones the more acid is required; but the usual amount is about 1 gallon of glacial acetic acid per ton of glue stock. Two and sometimes three cookings are made; the first cooking is usually of about 10 hours duration, lesser time is required for the subsequent cookings. Much larger amounts of preservatives are usually added to the stock prior to the cooking. The filtration and evaporation of the glue liquor is effected in the same manner as that previously described for skin glue liquor. The total amount of preservatives in the finished glue is often in excess of 1 per cent, although this varies with the nature of the preservatives added. Phenol, cresol, beta-naphthol, boric acid, and cresylic acid are commonly used. Larger amounts of essential oils are usually added to waste glues than to fish skin glues. The essential oils in common use include cassia, wintergreen, sassafras, artificial sassafras and peppermint.

Waste glues are often sold expressly for wood joining work, therefore small amounts of zinc oxide are often added to partially opaque the glue. For, if transparent liquid glues are used for joining work, the dried joint is dark and very noticeable.

Fish Head Glue.

The methods used for the conversion of fish heads into glue are not as well known as those used for fish skin and waste stock, although, needless to say, the methods are much the same. The washing is accomplished in the same manner, although larger washers are commonly used as larger quantities of fish-head stock must be handled to obtain the same quantities of glue. Two types of cookers are in common use; one resembles that used for the conversion of skin and waste stock except that it is much larger being about 12 feet long, 8 feet wide and 5 feet deep. The other type of cooker is a large pear-shaped steel boiler in which the stock is cooked with superheated steam.

Sodium bisulphite or sulphurous acid is often added to the stock just before the cooking is commenced; these agents effect a considerable bleaching.

Because of the relatively large proportion of bone in fish heads, much larger amounts of acid are used. Two gallons of acetic acid per ton of stock is the proportion commonly used. If the amount of acid used is reduced much below this figure the residue is difficult to press and dry.

Fish head glue liquors are evaporated according to the procedure described for skin and waste glue liquors. The same antiseptics are used for the preservation of the finished glue; larger amounts of essential oils are usually added to fish head glues in order to mask the disagreeable odor.

Since fish head glues are widely used for joining wood, sufficient zinc oxide is usually added to render them nearly opaque.

Yield of Glue from Stock.—The yield of liquid glue obtained from cod and cusk skin is usually between 60 and 80 gallons per ton of stock. Hake, haddock and pollack skins yield much less glue; the usual amount obtained is 35-45 gallons per ton. Trimmings and bones (waste) from salted ground fish yield about 25 gallons of liquid glue per ton, although as much as 30 gallons of glue is occasionally obtained. The best yields of liquid glue obtained from fish heads are 15 to 18 gallons per ton of stock; although the yield often falls as low as 12 gallons per ton.

Composition.

Fish glue of the usual viscosity contains from 50-55 per cent of dry glue and weighs from 9.5 to 10 pounds to the gallon. In addition to glue it contains about 1 per cent of preservatives, 0.2-0.4 per cent of essential oils, and usually a small amount of zinc oxide or some other white pigment; in addition from 0.5 to 1.0 per cent of ethyl or methyl alcohol is often found.

Comparatively few analyses of the dry matter of fish glue have been made. Dry fish skin and fish waste glues contain about 1 per cent of ash; the amount of ash contained in fish head glues varies, depending on the method of manufacture and the amount of pigment or other inorganic materials added during the manufacture of the glue. A sample of fish skin glue analyzed by the writer[1] had the following composition:

ANALYSIS OF ASH

Ash in dry matter	0.96%
Silica (SiO_2)	12.7
Calcium oxide (CaO)	10.5
Magnesia (MgO)	trace
Potash and soda (K_2O and Na_2O)	13.9
Sulphur trioxide (SO_3)	34.0
Phosphorus pentoxide (P_2O_5)	24.9
Chlorine (Cl)	3.2
Ferric oxide (Fe_2O_3)	trace
	99.2%

Bogue[2] has carried out the most detailed exact analyses of the dry matter of fish glue of any that have been published but unfortunately he does not state which kind of fish glue he analyzed. His results are given below:

NITROGENOUS CONSTITUENTS

Protein N	33.4%
Proteose N	42.3
Peptone N	21.9
Amino Acid N	2.4
	100.0%

PURIFIED* PROTEIN ANALYSIS

Ammonia N	5.15%
Melanin N	1.12
Cystine N	Trace
Arginine N	13.80
Histidine N	2.04
Lysine N	8.58
Amino N in filtrate	60.20
Non-amino N in filtrate	9.66
	100.55%

* Precipitated with 95% alcohol, redissolving and reprecipitating 4 times.

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[1] *Chem. Age, 29* (1921), 173-5.

[2] *Met. Chem. Eng., 23* (1920), 105-9, 154-8.

Fish glue owes its property of complete solubility in water at ordinary temperatures (20° C.) to its low content of gelatin, as is shown by its relatively low percentage of protein nitrogen, and its high proteose and peptone nitrogen content; the latter two being completely soluble in cold water.

Bogue has compared the composition of the amino acid groups of fish glue with that of bone and hide glues. He concludes:

> This glue (fish glue) shows higher ammonia, melanin and amino nitrogen of the filtrate, and lower non-amino-nitrogen of the filtrate than any other glue, but more nearly corresponds to the low grade bone glues than to the hide series. Only in its high amino nitrogen of the filtrate does it resemble the latter. The very low non-amino nitrogen of the filtrate in the case of both the fish products indicates a fundamental distinction from animal glues.

Examination of Liquid Glue.

Many liquid glues are marketed which are manufactured from materials other than fish stock. The quality of these glues varies greatly; and unfortunately all of the fish glues that are marketed are not of the highest quality. However, this is also the case with hard glues; as both bone and hide glues vary widely in properties. Methods of determining the quality of hard glues have been known for many years, but few liquid glue buyers are able to determine the quality of their glue by analytical methods. For this reason methods of examination of fish and other liquid glues will be outlined in some detail.

The properties desired in a liquid glue depend upon the use to which it is put. Glue suitable for joining work is considered the best type of liquid glue for general use. Special work such as labeling requires special glue and since each type of special work requires a different quality of glue it is obviously impossible in a work of this nature to consider all of the special glues. Liquid glues adapted for joining work will therefore be the only glues discussed.

Liquid glues used for joining work should possess high tensile and shearing strength under all ordinary weather conditions. Properties controlling strength include hygroscopicity, chemical composition, viscosity and flow at low temperatures. If a liquid glue is to be used in cool rooms, its gel point must be relatively low. The color and opacity of the liquid glue affect the appearance of the joint. Clear glues appear darker on wood than opaque glues provided the opacity is not caused by dark-colored pigments, i.e., blues, blacks or browns.

Methods of Examination.

Gel Point.—To determine the gel point of a liquid glue accurately it should be cooled very slowly and the temperature at which the glue ceases to flow noted. A simple rapid method, accurate within half a degree, is to cool rapidly a sample of the liquid glue in a test tube immersed in cold water noting the temperature at which flow ceases and then melting the gel in warmer water. The average of the melting point of the gel and the observed gel point is a close approximation to the true gel point.

Viscosity.—This property is easily determined in a Stormer viscosimeter if a 500 gram weight is substituted for the 100 gram capsule with which this machine is ordinarily equipped. Viscosity determinations are of the most value when the viscosities of a given glue are determined at a series of temperatures and plotted against the temperature on coördinate paper. The curve gives much information as to the flow of the glue at various temperatures, the concentration of the glue solution, and the presence of gel-inhibiting substances. Moreover, the gel-point of the glue is accurately indicated by the point at which the viscosity reaches infinity.

Moisture Determinations.—The procedure in determining the percentage of moisture should be uniform in all cases; heating for 5 hours at the boiling point of water will give satisfactory results.

Speed of Set.—When liquid glue is first applied to a wood joint, the wood absorbs a certain amount of water and in a short time, usually a minute or two, the liquid "sets" or gels and the joint attains some strength. This gelling, because of absorption of moisture by the object to which the glue is applied, is termed "setting." The time elapsing between the application of the glue and the gelling or preliminary drying of the liquid glue is known as the "speed of set." No accurate methods have been proposed for determining this property of liquid glues. A rough approximation of the relative speed of setting of various liquid glues may be gained by brushing a thin layer of glue on paper and noting the number of seconds elapsing before a skin forms on the surface of the glue. Such results are of no value unless they are compared with similar data obtained by use of glues of known qualities.

Ash Content and Composition of Ash.—It is very difficult to obtain glue ash, free from carbon, without volatilizing some chlorides and other easily volatilized inorganic substances. For this reason, the simple ignition of a weighed sample of glue does not give a true sample of ash. The samples used in the determination of solid matter may also be taken for the ash determinations. They should be moistened with standard calcium acetate solution and ignited according to the method[3] adopted by the Association of Official Agricultural Chemists.

Aside from indicating the total amount of inorganic materials in the glue, the ash content is of little value as an index of the quality of the liquid glue. An examination of the ash is of much more value to the chemist; the presence of large amounts of chlorides indicates that the glue is hygroscopic because of the presence of hygroscopic chlorides. Most manufacturers of fish glues consider the amount of chlorides as the best index of the hygroscopicity of the glue, and therefore a chloride determination is made on each batch of glue manufactured. The liquid glues are then graded according to the percentage of chlorides that they contain. The best fish glues should not contain more than 0.02 per cent of chlorine as chloride.

Drying Properties.—The relative rate of drying may be judged fairly by comparing the drying qualities of a sample of liquid glue when spread on a glass plate with those of a standard sample. The time required for a layer 0.2 cm. in depth to dry, at a given humidity and temperature, e.g., 25° C. and 70 per cent humidity, is noted and compared with the standard. The best grades of liquid glues dry to transparent, glossy films which are strong and brittle. If the dried film is easily powdered, the glue is of little value for most purposes.

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[3] *U. S. Dept. Agr., Bureau Chem., Bull. 107* (1907), 21.

Hygroscopic Properties.—If the completely dried film of glue is placed in a constant temperature, constant humidity room, or in a humidor over a sulphuric acid solution, it absorbs some moisture. The gain in weight is an index of the hygroscopic properties of the glue. The absorption of moisture softens the glue film to a greater or lesser degree. If the dried films are placed over 80 per cent sulphuric acid at 25° C., those which become sticky and of the consistency of molasses are very hygroscopic and are of little value for joining work; if the film becomes flexible the glue possesses slight hygroscopic properties.

Joint Strength.—In the manner in which strength tests are ordinarily carried out on glues, they are of little value in grading the glues. Even careful accurate experimenters are unable to check their results closely. The weather conditions—temperature and humidity—have an important influence on the strength of all glues (hide, bone, fish, etc.). In order to obtain uniform results, the testing of the strength of glues must be carried out in constant temperature, constant humidity rooms. Fair results are obtained by drying the joints in a humidor at 25° C. over 90 per cent sulphuric acid. Three different strength tests are used in the determination of the joint strength of glues, viz.: shearing, tensile, and breaking strength tests. Of these tests only the shearing strength test has been generally recognized as a standard method. The procedure recommended by the U. S. Forest Products Laboratory[4] is as follows:

Well-seasoned hard maple wood is sawed into two pieces 12 by 2.5 by 1 inches. The contact surfaces should be planed just before the glue is applied. The glue is spread on both of the contact surfaces; then the blocks are allowed to stand to permit the glue to soak in for about five minutes. They are then joined and placed in a press for at least fifteen hours, after which they are put in a rack and allowed to stand from 6 to 9 additional days. Each of the joints is sawed into four smaller joints. The blocks are broken apart by bringing a shearing strain to bear on the layer of glue between the two wooden halves of the joint in an Olsen Universal Testing Machine.

This method when carried out under uniform conditions of temperature and humidity gives admirable results with the weaker glues. The stronger glues pull a larger or smaller area of the wood out and thus the test may not indicate the full shearing strength of the glue. For such glues the tensile strength and breaking strength tests give more uniform results.

Color.—The color of liquid glues is most easily determined by clarifying the liquid glue with egg albumen and then matching the color with the glasses in a Lovibond Tintometer. Very light-colored glues are required for use on light woods. Darker glues may be used on dark woods without danger of making a conspicuous joint. Light-colored glues have a more pleasing appearance and therefore command a higher price than darker glues.

Permanence.—Another point of first importance in the consideration of the value of any liquid glue is its permanence. Not only must it retain its adhesive power indefinitely but it must retain its original appearance, i.e., no coagulation, precipitation or discoloration should appear on storage for long periods of time. The glue must, therefore, be preserved to prevent bacterial and mold growth and it must not contain any suspended matter that will settle out on standing. The glue should be neutral to litmus but slightly acid to phenolphthalein. One of the best tests that may be applied to a liquid glue to determine its permanence is storage at a slightly elevated temperature (37° C.). If liquid glue remains free from bacterial decomposition and other changes during a month's storage at this temperature, it is likely that it will keep indefinitely at ordinary room temperatures, provided it is properly preserved to prevent mold growth.

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[4] *Nat. Advisory Committee for Aeronautics, 66* (1920).

Interpretation of Analytical Results.—If a liquid glue is to be used for joining work, the properties which are of prime importance are permanence, adhesiveness or strength, and hygroscopicity. If the glue is lacking in any one of these three qualities it is of no value for use in joining wood. Other properties such as gel point, viscosity, color and odor are of minor importance in most cases. Where the glue is to be used for special work, such as joining glass, other properties, for instance color and elasticity, become of importance.

In buying glue, viscosity, moisture content and speed of set should be taken into consideration; for these properties determine the relative cost of liquid glues. Obviously, more glue must be applied to joints in the case of liquid glues of low viscosity and high moisture content than when glues of high viscosity and low moisture content are used. If the liquid glue sets too quickly after it is applied, it will be impossible to spread the glue uniformly, and therefore more glue must be applied in making the joint than would be the case if a slower setting glue were used.

By-Products.

The residue in the cookers left after the final cooking and draining contains a considerable quantity of glue liquor. This residue is placed in canvas bags in a hydraulic press and pressed, which accomplishes the dual purpose of recovering the glue liquor and of partially drying the chum. The recovered glue liquor is added to the main bulk of the liquor and evaporated. The residue in the hydraulic press is dried further either by direct or indirect heat in a long revolving cylindrical drier and is then sold either as feed or as a fertilizer. At one time, a large proportion of the dried chum was used for the preparation of fertilizer but the demand for this material for use as a poultry feed grew rapidly and now nearly the entire production is sold to poultrymen.

The dried chum is an excellent poultry feed as it contains about 50 per cent of protein in an easily digestible form; fish head and waste chum contain a high percentage of calcium phosphate. The latter constituent supplies calcium for the egg shell and phosphorus for the egg yolk.

Chum produced from "skins" contains (water-free basis) on the average 12.2 per cent nitrogen, calcium and magnesium phosphates 25.5 per cent; from "waste" 11.1 per cent nitrogen, calcium and magnesium phosphates 30.0 per cent; from "fish heads" 10.0 per cent nitrogen, and calcium and magnesium phosphates 36.6 per cent. The average composition of the mixed chum prepared for chicken feed is as follows:

Moisture	12.0%
Protein (Nitrogen × 6.25)	53.0
Calcium and magnesium phosphates	27.0
Fat	1.5
Salt	1.5
Crude fiber	0.8
Other ash constituents	4.2
Total	100.0%

Many have claimed that the feeding of fish meal imparted a fishy flavor to animal products. This assumption is not well founded as has been pointed out on page 473.

Uses.

Fish glue is widely used for a large variety of purposes. It is the only glue manufactured that needs no further preparation for all general uses. Many ready to use glues are prepared from starch and dextrin but these are limited in use to special purposes such as labeling and box making. The best grade of fishskin glue is the only satisfactory glue for use in the production of half-tone plates for photo-engraving work. It is also used to some extent in the production of zinc line plates.

Fish glues are used largely where flexible glues are desired, e.g., in the manufacture of court plaster, labels, and stamps, and in the binding of books. Liquid fish glue is also almost universally used where small amounts of a strong, ready-to-use adhesive are required, as for small repair jobs about the house, for shoe repairing, and for general repair work. Fish glue is blended with hide glue in the manufacture of belt cement for leather belts. Large quantities of the cheaper grades of fish glue are used in various sizing operations as this glue stiffens materials yet is somewhat flexible. Some fish glue is used in the chipping of glass in the production of translucent glass. Large quantities of this glue are used by furniture makers, boxmakers and other manufacturers for general joining work.

Fish Isinglass and the Isinglass Industry.

Location of Industry.

Isinglass is manufactured in many countries in nearly all parts of the world. Russian isinglass prepared from sturgeon sounds is perhaps the best known isinglass and is usually considered the best quality on the market; but good grades of this valuable material are also manufactured in Iceland, Newfoundland, Canada, India, the Philippine Islands, Venezuela, Brazil, the East and West Indies, and the United States.

Raw Materials.

The famous Russian isinglass is made from the sounds or swimbladders of several varieties of sturgeon (*Acipenser huso* or beluga, *A. ruthenus* or sterlet, *A. sturio* or common sturgeon, *A. stellatus* or starred sturgeon), of catfish (*Silurus glanis*), and of carp (*Cyprinus carpio*) which are caught in the Volga and other rivers, in the Caspian and Black Seas and in the Arctic Ocean. In Iceland, cod and ling sounds are the chief source of isinglass. In Newfoundland, Nova Scotia and New England, hake and cod sounds are used for the manufacture of this material, hake sounds being the principal source. The squeteague, which is caught in large quantities along the coast of the middle Atlantic States, also has been used for the preparation of American isinglass. In Venezuela and Brazil, the *Siluridæ* are chief source of isinglass.

Isinglass is in reality merely carefully washed and dried fish sounds made into special forms by mechanical means. The fish sound which is also called the air bladder or swim-bladder, is a hollow compressible sac, containing air, situated in the abdominal cavity just below the vertebral column. Its principal function is mechanical, for, since it is compressible, it serves to regulate the specific gravity of the fish and enables the fish to rise and sink or to maintain its level in the water. The size of this organ varies greatly in different species; in the sturgeon, hake, catfish and carp it is a large, well developed organ. In some fishes the sound is securely fastened to the backbone, the intestines and the abdominal wall, while in others it is nearly loose in the abdominal cavity. The swim-bladder consists of several tunics, the outer layer of which is thick and fibrous; the collagen contained in this layer is the source of isinglass. The inner layer of tunics is thin, contains crystalline substances such as guanin; and often has a silvery luster.

No complete analyses of fish sounds have been published; but the composition of the fresh sound probably does not differ greatly from that of the prepared isinglass as the washing and cleaning removes only a small amount of membranous material and dirt. The analyses of the prepared isinglass are presented on page 490.

Methods of Manufacture.

Russian Isinglass.

The best grades of Russian isinglass are prepared from sturgeon sounds. If fresh sounds are used they are split open and carefully washed either in cold or warm water to remove the blood, membranes and any adhering extraneous matter. If the sounds have been previously preserved by drying, they are soaked in water for several days with frequent changes of water to soften them and permit the removal of membranous matter.

The cleaned sounds are treated in various ways depending upon the form of isinglass desired. Common forms of Russian isinglass are long staple, short staple, leaf book, and cake isinglass.

Bogue [5] has described the manufacture of leaf isinglass:

> After the washing is complete the sounds are cut longitudinally into sheets. These are laid out to dry by exposure to the sun and air upon boards of linden or basswood. During this process the inner layer, which is the layer consisting of pure isinglass, is uppermost, and after a partial drying it may be removed from the coarser external lamellæ. These finer sheets are placed between cloths to protect them from the flies, and are subjected to heavy pressure to flatten them.

[5] *Chem. Age, 30* (1922), 183-4.

After thoroughly drying they are assorted and tied up into packages for export, containing 10 to 15 sheets and weighing about 1¼ pounds. These packages are commonly shipped in lots of eighty, sewed up in a cloth bag or inclosed in lead-foil. The external layers are softened with water and a considerable amount of gluey material scraped off which is moulded and dried. This is used as an inferior isinglass. The residue, together with trimmings from the sounds and other parts of the fish, is boiled with water to produce a fish glue.

The "staple" form of isinglass is produced by rolling each bladder and folding around a few pegs set in the form of a horseshoe. Book isinglass is prepared by folding the sounds and then covering them with a damp cloth.

American Methods.

The best quality of American isinglass is prepared from the sounds of hake caught in deep waters off the coast of Nova Scotia. One ton of these fish yields from 300 to 500 large swim-bladders weighing from 40 to 50 pounds. Hake sounds from shallow waters are smaller and of a lower grade. The hake sounds are removed from the fish when the fish are dressed, which operation is usually carried out on board the fishing vessel soon after the fish are caught. If the fishing grounds are far from shore, the sounds are immediately salted in barrels to prevent their putrefaction.

Upon arrival at the isinglass factory, the sounds are slit open and thoroughly washed and the black outer membrane is scraped off. The sounds are then dried in the open air, usually on large trays which may be quickly taken in in case of rain.

The final step in the manufacture of isinglass is carried out only during cool weather on account of the difficulty of preventing softening and putrefaction during the warmer months. The process is very simple and merely involves the union of the sounds into a long ribbon. This is accomplished by soaking the freshened, scraped and air dried sounds in water for four to six hours or until they become soft and pliable. The softened sounds are usually run into a cutting machine provided with a roller and a set of knives which chop the sounds into small pieces. The chopped sounds are mixed and macerated between a set of iron rollers, from which the material passes to so-called sheeting rollers. These are hollow iron rollers, through which cold water flows, provided with a scraper which removes all isinglass adhering to the rollers. Thus the isinglass is converted into sheets one-eighth to one-fourth inch thick, 6 to 8 inches wide and of any length desired. These long sheets are finally passed through ribbon rollers until the ribbons produced are one-sixty-fourth of an inch thick, the width being the same as that of the sheets. The ribbons must be quickly dried to prevent putrefaction. This is accomplished in a few hours by suspension in moderately warm light rooms. The ribbons are then rolled on wooden spools into coils weighing less than a pound each.

Composition and Properties of Isinglass.

Isinglass does not dissolve in cold water but merely swells slowly and absorbs some water but not nearly the amount that would be taken up by a similar weight of gelatin. Isinglass has been popularly considered to be pure gelatin, but it really is collagen and does not become gelatin until after it has been heated with water. Under these conditions, it hydrolyzes to form gelatin which dissolves and upon cooling forms a tough gel, resembling closely gels formed by the cooling of animal gelatin solutions. If this gel is dried, it then is found to possess all the properties of hide or bone gelatin; it will be clear and almost colorless and will make a glue of great adhesiveness. Isinglass always possesses a distinct fishy odor. It is insoluble in alcohol.

Isinglass should contain but little ash and a low percentage of matter insoluble in hot water. The best grades of Russian isinglass contain less than 0.50 per cent of ash and not more than 3.0 per cent of matter insoluble in hot water.

Since isinglass is very valuable, attempts are often made to adulterate it. Gelatin, blood fibrin, agar-agar and several other substances have been used as adulterants. Gelatin is sometimes rolled between layers of isinglass. This adulteration may be easily detected by the microscopic examination of the jelly formed by soaking the material in water, as the isinglass retains its fibrous structure whereas the gelatin does not.

Bogue [5] has carried out detailed analyses of Russian isinglass. His results are given below:

NITROGENOUS CONSTITUENTS OF RUSSIAN ISINGLASS

Protein N	91.0%
Proteose N	4.4
Peptone N	4.5
Amino acid N	0.1
Total	100.0%

DISTRIBUTION OF AMINO-ACID GROUPS IN PROTEIN OF RUSSIAN ISINGLASS

Ammonia N	3.98%
Melanin N	0.68
Cystine N	0.00
Arginine N	14.20
Histidine N	2.33
Lysine N	6.06
Amino N in filtrate	58.65
Non-amino N in filtrate	13.59
Total	99.49%

In comparing the results of his amino acid analyses of isinglass proteins with those of the proteins of hide, bone, and fish glues, Bogue says:

> The arginine nitrogen is higher and the lysine nitrogen lower than in any other analysis. The ammonia nitrogen is high and the non-amino nitrogen of the filtrate is low, but in general the figures correspond somewhat more closely to Van Slyke's analysis of gelatin . . . than any other glue. It is also apparent that in most of the groups the high-grade hide glues more nearly correspond in value to the analysis of isinglass than the bone glues.

Uses.

The most important use of isinglass is in the clarification of wine and beer. Recently excellent methods of filtration of beer have been generally adopted therefore isinglass is not now commonly used as a fining agent for beer. White wines are usually clarified by treatment with isinglass. The fining process is simple; the isinglass is first swollen in water and then in wine until it is nearly transparent. It is thoroughly beaten with more wine after which a little tartaric acid is added. The isinglass is then strained through linen and stirred into the bulk of the wine. The solution is not heated so the isinglass does not dissolve. Thus although the isinglass is disintegrated into a finely divided suspension its original fibrous structure is not destroyed. As this finely divided suspension settles slowly to the bottom it entangles in its netlike meshes the colloidal bodies that produce the undesirable turbidity. Only a small amount of isinglass is required to clarify a large quantity of wine. A single ounce of isinglass will usually clarify 200 to 500 gallons of wine in 8 to 10 days.

Formerly isinglass was used for the preparation of edible jellies and in the manufacture of confectionery but since high grade gelatin has become relatively inexpensive this use has become obsolete as have also most of the uses of isinglass as an adhesive and as a size.

Isinglass is still used to a limited extent in the manufacture of court plaster. White [6] describes the process as follows:

> The proportions used are 10 grams isinglass, 40 grams alcohol, 1 gram glycerin, and water and tincture of benzoin in sufficient amount. The isinglass is dissolved in enough water to make the total weigh 120 grams. One half of this solution is spread in successive layers with the aid of a brush, on taffeta stretched on frames; each layer is allowed to dry before the next is applied. The second half of the isinglass solution is mixed with alcohol and glycerin and is applied to the cloth in a similar manner. The reverse side of the taffeta is covered with a layer of tincture of benzoin and allowed to dry. The above quantities are sufficient to cover a piece of taffeta 38 centimeters square.

Other uses for isinglass are in the preparation of special cements, as a constituent of a waterproofing composition and various other miscellaneous purposes.

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[6] Fish Isinglass and Glue, *Bureau Fisheries, Doc.* 852.

Chapter 26.

Manufacture of Leather from Marine Sources.

By ALLEN ROGERS.*

From time immemorial the pelts of animals have been utilized by man for his comfort and protection, but through all these ages practically no consideration has ever been given to the use of skins from fish. True it is that certain kinds of marine leather have found a limited use, but such leather has been derived from the seal, walrus and porpoise, which marine creatures closely resemble the land animals. It is only within the past few years that any attempt has been made to utilize the skins of fish for commercial purposes. During this short period, however, great strides have been made and the possibility of converting the skins of sharks and rays into a marketable product has become an assured success. In dealing with this subject, therefore, it seems wise to first consider those skins which have been the longest in use and finally those of more recent introduction.

Sealskins.

In discussing this subject we must at once divide sealskins into those which are used for furs and those used for the production of leather. As the conversion of the pelts into furs is described in Chapter 35, the methods employed will not be considered here. The hair seal has no under coat of fur and is, therefore, used only for making certain kinds of leather.

Depilation.—On arrival of the skins at the tannery the first step is to wash the skins to remove salt and dirt and, if not previously blubbered, the excess of fat must be eliminated. To aid in the removal of the blubber, the skins are soaked in water containing a small amount of sodium carbonate and the stock then worked over a rounded beam with a blunt knife. The fleshed or blubbered skins are then ready for depilation. This consists in treating the skins in a paddle with water containing a quantity of slaked lime. The action of the lime is to swell up the fiber bundles, remove the cementing material and loosen the hair and epidermis. In addition to this the lime has a certain action upon the fat thus partly saponifying it and causing it to be more easily eliminated. The time consumed in depilating depends somewhat upon the nature of the skin, but more especially upon the product to be manufactured. For skins which are to be used for oil tannage, where softness is desired, a fairly long liming is given. For the production of fancy leather, used in making bags and cases, a shorter liming is employed. The usual method of procedure consists in placing the skins in a paddle containing a mixture of lime and sodium sulphide. From day to day, the skins are passed to stronger solutions, and, finally, into very strong lime solutions to which no sodium sulphide has been added.

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Unhairing.—When the hair has become sufficiently loosened to rub off under the hand and the skins are in a properly plumped condition, they are placed over a beam and the hair and epidermis is removed with a blunt knife. In place of the hand operation, unhairing machines are now commonly used for this purpose. After unhairing, the stock is washed in drums with running water until perfectly clean.

Bating.—In order to remove the lime which has been absorbed during depilation and to again bring the skins to a soft and flaccid condition, they are now bated. This operation formerly consisted in running the skins in a warm fermenting infusion of pigeon or hen manure. In recent years, however, this objectionable procedure has been superseded by more scientific methods in which a combination of chemical and enzyme action is utilized to secure the results desired. The two most commonly used products are "Oropon" and "Puerine." Both of these substances contain ammonium chloride and an extract from pancreas. The first serves to remove the lime, while the second acts upon the albuminous matter of the skin causing a smoothing effect upon the grain and an opening of the stock. The time of bating depends upon the product to be manufactured, but it may be said that the longer the bating the softer the resulting leather.

Photo by E. C. Johnston.

Fig. 171.—A herd of sea lions. These animals furnish skins, from which valuable leather is made.

Tanning.—Most sealskin leather is tanned with sumac, or a combination of sumac with some other vegetable tanning material. One method which gives very good results consists in milling the skins for one hour in a 10° barkometer solution of quebracho extract. This serves to set the grain. The skins are then transferred to a paddle containing a 12° liquor where they remain until tanned, the strength of the liquor being gradually increased to 30°. The tanning should be complete in about one week. When tanned the skins are milled for two hours with a strong sumac liquor and, after being set out, are hung up to dry. The dried skins are dampened in water, set out again, sometimes shaved, and while yet moist are colored as desired. For most purposes, the colored skins are tacked out on boards to dry again.

Finishing.—The skins on being stripped (taken from the boards) are usually given a coat of season, and while in a damp condition are rolled on the jack. When a very bright finish is required, the stock is again seasoned with a mixture containing blood albumen, and, when this season is bone dry, the skins are subjected to friction on the glazing jack. To bring up the grain so characteristic of sealskin leather, the stock is boarded by hand or on the machine. This boarding consists in rolling the skins in such a manner as to produce miniature wrinkles running at different angles along the grain.

Walrus Skins.

The same procedure as for sealskins is carried out for this class of leather. The resulting product is too heavy for ordinary purposes and must be split to the weight desired.

Sharkskin Leather.

Sharks as well as other fish carry a protective coating, but unlike the hair bearing creatures this coating takes the form of scales, or a calcareous deposit known as shagreen. Before the skins can be utilized for leather, this shagreen, like the hair and epidermis of the land animals, must be removed. The oldest method for removing the shagreen consisted in scraping the surface with a heavy rasp or file. This operation, as may be well imagined, was time consuming, very laborious and exceedingly uneconomical. The leather resulting from this process was not a commercial product and on account of its unsatisfactory appearance found no ready market. For abrasive purposes and for sword hilts, a certain amount of raw sharkskin was used, but, with the lessening demand for swords and the introduction of cheap abrasives, its application for the purposes mentioned is a thing of the past.

The first real advance in the production of sharkskin leather on a commercial scale dates back to 1919 and 1920, when Kohler developed and patented a process for removing the shagreen from vegetable tanned shark skins, and the author[1] developed and patented several processes for removing the shagreen from the raw skin. These patents were assigned to the Ocean Leather Company which company has done more than any other concern to place this industry on a stable basis. In fact, to-day, the only problem confronting the industry is that of securing the necessary quantity of skins to meet the ever increasing demand for the finished leather.

Catching.—Several methods are employed in shark fishing, but the one which gives the best results consists in the use of gill nets. These nets are about 300 yards in length and about 12 feet deep. They are anchored across the path known to be followed by food fish, and as the meshes are eight inches in diameter any ordinary fish will pass through. The sharks, however, being so much larger and following in the wake of the fish become entangled in the meshes and are so retained. The catch of course varies with fisherman's luck and may be from nil to any number. The largest haul for one net in the experience of the author has been forty-eight. The crew of a fishing boat is three men and the best boat for the purpose is the Seabright dory. In hauling the net, one end is gathered up and the boat pulled alongside until a fish comes to view. The shark is then brought to the surface, and with a sharp blow on the head is rendered harmless. A hook is then placed in the mouth and by means of a small derrick he is pulled aboard as shown in Fig. 172.

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[1] U. S. Pat. 1,338,531 (1921).

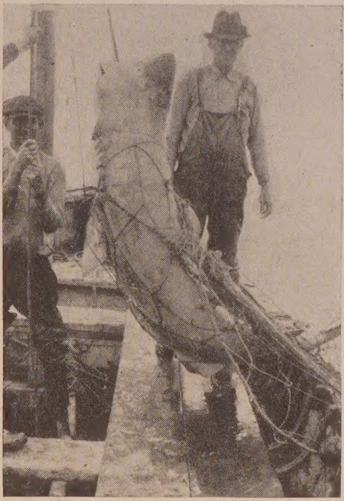


FIG. 172.—Taking a shark from net.

Removal of the Skin.—On arrival at the dock, the fish are at once skinned. This is done by cutting down the back from head to tail, and by means of short strokes of the knife the skin is worked off the side and by a rolling motion is separated from the belly. This method of skinning gives a uniform pattern of a V-shaped design which is a solid skin except for the opening at the pectoral fins. At some stations the skin is stripped off by using a tripod and utilizing the weight of the fish as an aid in separating the pelt. The flayed skin is next worked with a sharp knife over a rounded beam in order to remove the adhering flesh. When properly cleaned, the skins are given a liberal coat of salt and placed in piles to cure. When the cure is complete, the skins are rolled into bundles for shipment to the tannery. Fig. 175 shows a cross section of a shark skin in which the leather-forming fibers may be seen.

Tanning Operations.—As the skins arrive at the tannery, they are placed in pits containing fresh water, which serves to remove the salt and bring them to a soft condition. They are then transferred to lime liquor in order to open up the fiber bundles and to remove the cementing material, the same methods being followed as for animal skins. Similar to the handling of hides they are fleshed on the machine and then bated to remove the excess of lime and to open up the stock.

Vegetable Tannage.—If the skins are to receive a vegetable tannage, they are placed in a paddle containing a solution of tanning extract. The strength of the liquor influences the resulting product, the same precautions being observed as in the tanning of animal hides. When the skins have absorbed their required amount of tannin, they are removed from the paddle and washed. At this stage of the process, the shagreen is removed by milling with an acid solution, the skins being then well washed to remove the excess of acid. They are finally fat-liquored to prevent hardening and are hung up to dry.

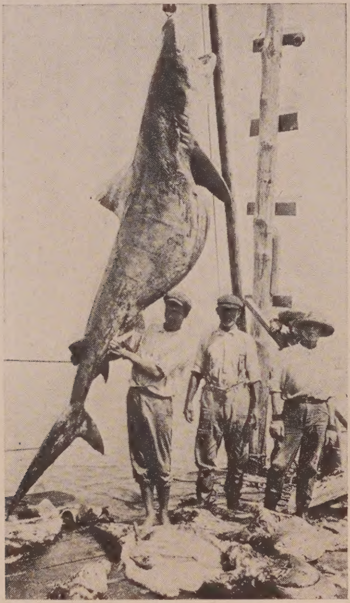


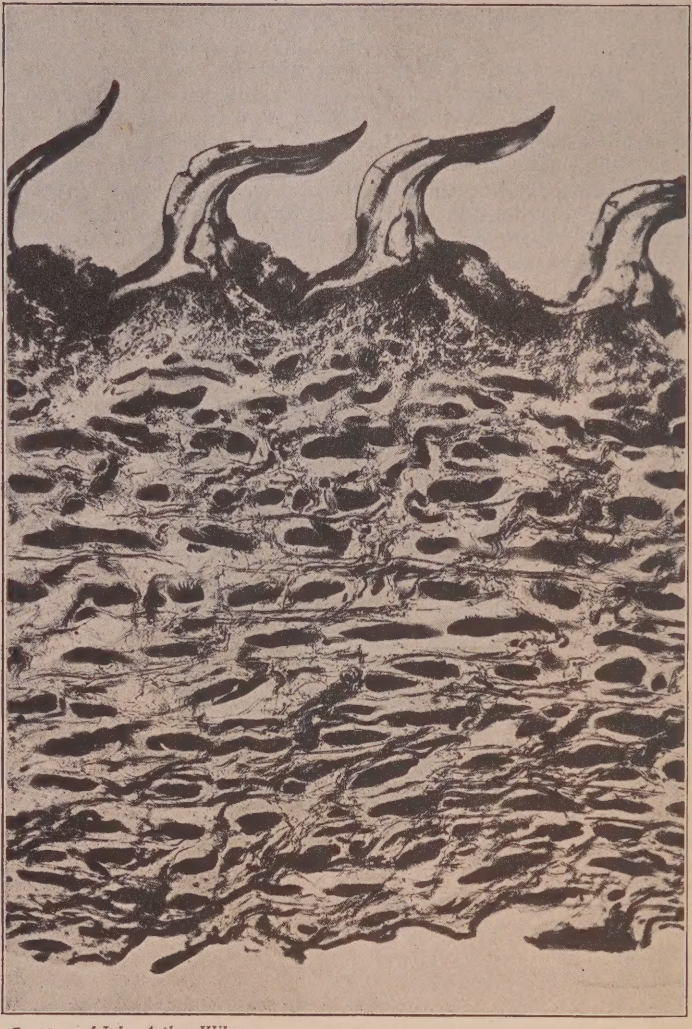
FIG. 173.—Skinning a tiger shark.

Finishing Operations.—The dried skins are dampened back with water and ether, colored with dyes or pigment finished. The final finishing is done on a rolling, or glazing jack, or on the brush machine as desired. By adjusting the tannage either a smooth or shrunken grain may be obtained. The shrunken grain is especially in demand as it produces a very pleasing article when manufactured into bags and cases.

Chrome Tannage.—For the manufacture of chrome tanned shark-skin leather, the shagreen must be first removed, after which the skins are pickled with salt and sulphuric acid and then run in a solution containing basic sulphate of chromium and salt. This operation is usually carried out in a drum, and the test to determine when the stock is tanned depends upon the fact that a chrome tanned leather will not curl when placed in boiling water. When thoroughly tanned, the skins are horsed up over night to allow the chrome to set and are then returned to the drum for neutralization. This operation consists in running with a solution of sodium bicarbonate and in clear water. The chrome tanned stock must be shaved to secure an even condition on the flesh side. This is done on a machine which carries a set of spiral knives, and, as the knife revolves, the skin is placed against the cutting edges.

Fig. 174.—A cub shark.

Coloring.—In order to color chrome tanned leather, the stock is first run in a solution containing tannic acid, for which purpose sumac or quebracho extract is usually employed. The purpose of this material is to act as a mordant for the dyes which are used to produce the color. The time in the mordant is about one-half hour and about the same time is required for the color. After coloring the skins are fat-liquored with a sulphonated oil and then hung up to dry. The skins on coming from the dry loft are packed in damp sawdust to slowly moisten, or as the tanner calls it, "to sammie." When in the proper condition, they are worked on a machine to soften and stretch them, the machine being called a staker. When well stretched and as soft as desired, the stock is tacked out on boards and again allowed to dry. On removal of the dry skins from the boards, or stripping, they are given a coat of seasoning and are then rolled or glazed as the demand may dictate.



Courtesy of John Arthur Wilson.

FIG. 175.—Vertical section of shark leather.

Thickness of section: 50 u.	Eyepiece: 5X
Stain: none	Objective: 16-mm
Tannage: vegetable	Wratten filter: B-green

Magnification: 75 diameters.

Ray Skins.—Many species of fish are included under this head such as skates, devil-fish, and sawfish. Their skins resemble those from sharks in that they carry a layer of shagreen and so must be handled in a manner quite similar to that described for sharkskins.

Cod Skins and the Like.—Each year millions of fish are caught for food purposes, but practically no attempt has ever been made to utilize their skins. There is a field open for development along this line and from the work already carried out by the author the problem of producing a marketable product does not look to be a difficult one of solution. Figs. 177, 178 and 179 show cross sections of cod, halibut and salmon skins, all of which have leather-forming fibers.

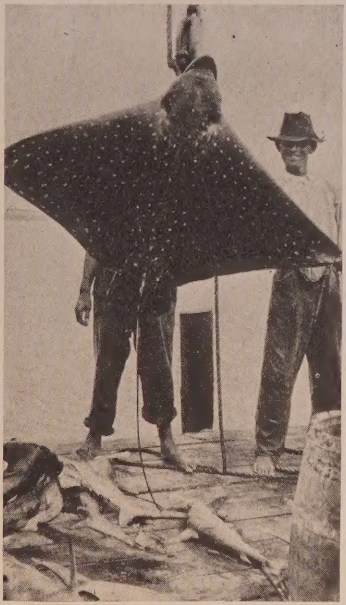
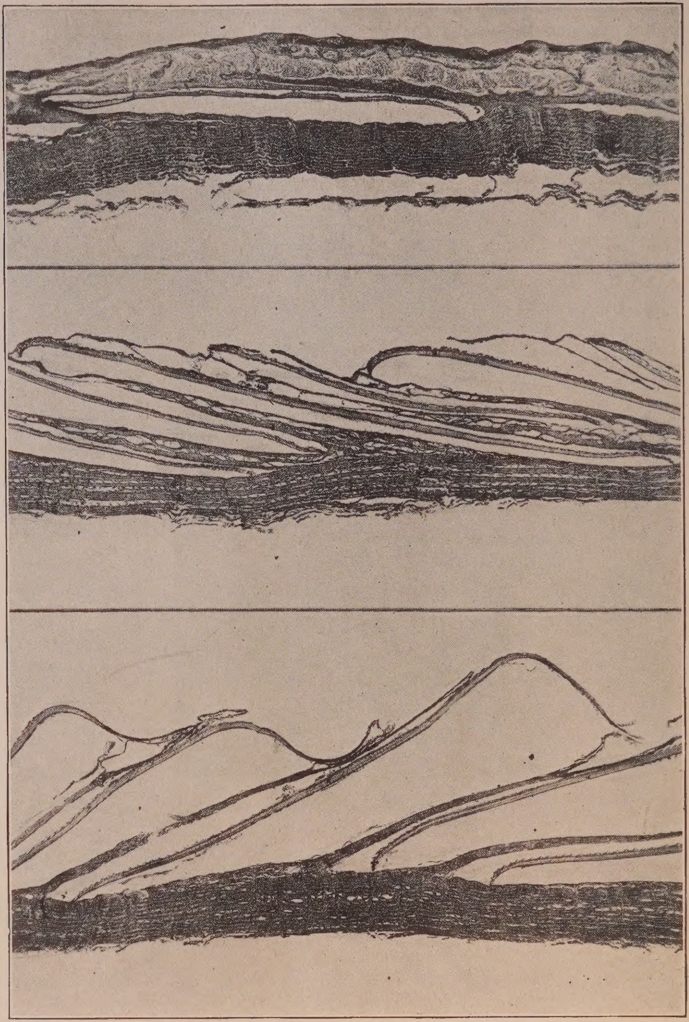


FIG. 176.—Spotted sting-ray or lady ray, *aëtobatus narinari.*

Porpoise Skins.

The porpoise, dolphin and blackfish which are names often applied to the same species of fish have been utilized for years as a source of leather. Their skin is very heavy and under the dermis there is a thick layer of blubber which must be removed before tanning. This is done in a manner very similar to that described under sealskins. Recent investigations, however, have shown that this fatty layer may also be easily separated on the belt knife splitting machine and the time factor therefore greatly reduced.



Courtesy of John Arthur Wilson.

FIG. 177.—Vertical section of halibut skin.
FIG. 178.—Vertical section of cod skin.
FIG. 179.—Vertical section of salmon skin.

Location: side
Thickness of sections: 20 u.
Stains: Friedlander's logwood, Picro-indigo-carmine

Eyepiece: none
Objective: 32-mm
Wratten filter: H-blue green
Magnification: 17 diameters

The blubber, which is separated from the hide proper, is heated in kettles or rendered in order to obtain its oil content. The skin from the porpoise, as well as from the other species, has on its outer surface a peculiar covering known as the rubber layer. This layer is readily separated by liming and can be easily removed over the beam or on the unhairing machine. The limed skins after beaming are bated to remove the excess of lime, and may be tanned either by the vegetable, chrome, or oil process.

Tanning Processes.—In the tanning of porpoise skins with vegetable tanning materials, the bated stock is placed in a paddle containing a dilute tannin extract. As the union of the tannic acid with the hide substance progresses, more and stronger liquors are required, which strength is obtained by the addition of concentrated extracts to the paddle. The time required for tanning is from one week to ten days and the tanned stock may then be finished in any way desired. In recent years, considerable porpoise leather has been made to imitate Cordovan and produces a very worthy substitute.

Porpoise Lace Leather.—One of the chief uses for porpoise skins in the past, and to a certain extent at the present time, is in the production of lace leather. This is a very strong product and is used for lacing up machinery belting. The method employed in producing lace leather consists in first tanning the stock, after coming from the bate, with a mixture of alum and salt. To accomplish this the skins are run in a drum with a mixture of about five per cent of aluminum sulphate and five per cent of common salt, to which is added about one-half per cent of sodium bicarbonate. The skins readily take up this mixture, and, when penetration is complete, they are hung up and allowed to become bone dry. The longer the skins remain in this dry condition the better the resulting leather. On removing from the dry loft, the skins are dampened slightly with water and placed in piles to sammie or in other words to become uniformly moist. When in the proper moist condition the stock is transferred to a mill and four per cent of cod oil introduced. The drum is set in motion, and, after running for one hour, another four per cent of oil is added. At the end of two hours more, the oil should all have been absorbed, when a third and final portion of four per cent is placed in the drum. The final milling should require about three hours when the skins are taken out and piled down over night. The following day, the stock is hung up and allowed to become thoroughly dry. When thoroughly dry, the skins are dampened uniformly and again piled down to temper. This time considerable heat is generated due to the oxidation of the oil, therefore, care must be taken to avoid overheating with consequent damage to the stock. At the end of twenty-four hours, the skins are again hung up to dry in a room the temperature of which is about 140° F. If oxidation is not complete, the stock is again dampened, tempered and stoved. By this time the skins should be thoroughly tanned and are dampened, oiled off with a mineral oil, and rolled.

Miscellaneous Leathers.

Whale-Hide Leather.—The hide of a whale like the skin from a porpoise carries a very heavy blubber. The hide itself is much thicker than porpoise, but up to the present time no satisfactory use has been found for the product. It may be tanned, by the same methods as given under porpoise leather.

Fish Intestines and Stomachs.—The large intestines of the whale have been suggested as a source of leather. Considerable work on this material has been carried out by the author and the results obtained indicate that it may be used to advantage for certain purposes. The intestines of the porpoise have also been investigated by the author and from them it has been possible to produce a very satisfactory substitute for cat gut used in producing surgical sutures and for musical strings. Some work has been done upon shark stomachs, but nothing definite up to date has been accomplished. Shark and ray tubes, however, have been tanned by the writer, and the resulting leather demonstrated to be of commercial value.

Chemical Reactions Involved in Tanning.

In the study of leather manufacture, like every other manufacturing process, the chemical reactions involved form the basis upon which a complete understanding depends. Let us, therefore, consider the reactions taking place in the order of their occurrence.

Liming.—In the removal of the hair or for plumping the stock a solution of milk of lime is generally used. This milk of lime is a suspension of calcium hydroxide in water, or what is commonly known as slaked lime. Lime is obtained by "burning" limestone or calcium carbonate whereby the gas, carbon dioxide, is driven off and calcium oxide remains. This calcium oxide, when treated with water, is converted into calcium hydroxide which, when mixed with water, forms a suspension known as milk of lime. The action of the calcium hydroxide upon the hide substance is to form soluble compounds with the albuminous materials, thus causing partial hydrolysis with a resulting swelling and opening up of the fiber bundles. To a certain limited extent, also, the lime tends to saponify the fatty matter, thus making its removal less difficult in the subsequent operations.

Bating.—The action of the bate through the ammonium chloride present is to remove the excess of lime, and by the enzymes which it contains a depleting effect upon the hide substances is brought about. The removal of the lime and the depleting action produce the soft and flaccid condition required before the actual tanning.

Vegetable Tanning Materials.—The tanning solutions proper contain primarily the substance known as tannic acid. This substance combines with the gelatinous substance of the hide forming an insoluble and non-putrescible product. Tannic acid alone, however, will not make a satisfactory leather as it requires the presence of other bodies, spoken of as non-tans in order to secure the desired results. The source of vegetable tanning agents is from the barks of numerous trees such as oak, chestnut and hemlock, the wood of some trees such as quebracho, and the leaves of certain shrubs such as sumac. From all of these materials, the real tanning substances are obtained by extraction with water.

Chrome Tannage.—In the production of leather by the chrome process, the active substance is basic sulphate of chromium. This compound may be produced in various ways, but in practically all cases results from the reduction of sodium dichromate in the presence of sulphuric acid. The tannage is due to a deposition of chromium hydroxide and lower basic substances about the fiber bundles. Chrome tannage has the advantage over vegetable tannage in that the time required is much less and the resulting leather has characteristics which are very desirable for use in the manufacture of shoes.

Dyeing and Finishing.—In the dyeing of leather, natural colors as well as coal tar dyestuffs are employed. For bright shades, the basic dyes are most commonly used, but for certain purposes both acid and direct colors are applied. Within the past few years, pigment finishes have met with considerable favor and are now being used to a very large extent. In order to give to leather the proper strength, fullness, and desired appearance, it is necessary to introduce certain fats and oils at various stages in the process of manufacture and to apply special finishes, for producing a bright or dull appearance as the demands may indicate. The most common oils and fats are cod oil, neatsfoot oil and dégras, while the finishing materials consist of gum tragacanth, Irish moss, egg albumen, shellac and gelatin.

To give all of the details necessary in producing leather from the various skins mentioned in this chapter would take more space than can be devoted to the subject in a book of this character. The reader who is especially interested, however, in securing more information on the general subject of leather manufacture is referred to the following list of references:

Bennett, H. G., "The Manufacture of Leather." London, 1910.

Lamb, M. C., "Leather Dressing." London, 1907.

Procter, H. R., "The Principles of Leather Manufacture." London, 1922.

Rogers, A., "Shark-skin leather." J. Am. Leather Chemists Assoc., *13* (1918), 528-30.

———, "Industrial uses of the shark and porpoise." Chem. Eng., *27* (1919), 135-6.

———, "Utilization of the shark for food and leather." J. Ind. Eng. Chem., *12* (1920), 293.

———, "Practical Tanning." New York, 1922.

Wilson, J. A., "The Chemistry of Leather Manufacture." New York, 1923.

Chapter 27.

The World's Oyster Industry.

By J. S. GUTSELL.*

The oyster industry, like so many of the great fisheries, is a very ancient one. Doubtless its origin is to be found in the use of oysters by primitive, prehistoric Asiatic or European peoples. Clearly, with such a primitive beginning its development must wait upon that of population and commerce. It is supposed to have been carried on to some extent by the Greeks and was highly developed by the Romans and ancient Chinese.

The beginning of oyster culture, obviously much more recent than the first use of oysters, is still so old as to be shrouded in antiquity. Although the simplest obvious advance would be protection of the natural oyster beds, it is not clear that this actually was the first or even a very early measure. Apparently the first actual step in oyster culture was the taking of oysters from the natural beds and placing them where they would be protected, be quickly available when desired, and, for a more particularly cultural object, be improved in condition or even be grown from small size to maturity. Before the foundation of the Roman Empire, it had developed to a great extent in Italy. It is even stated that oysters were shipped to Rome from England.

A special and the most decidedly cultural aspect of this transplanting was the taking of small oysters, called "seed" in America and "brood" in England, from the natural beds for growth in private beds. Presumably this was practiced in Roman oyster culture. In France, if it was not carried over from antiquity, it evidently made a rather early development, for by the latter part of the fourteenth century apparently it had become advisable to limit the taking of oysters below the size of a shilling.

The next step, which marks the highest stage yet attained, was the putting out of cultch or spat collectors. Like the other advances, its advent is obscure. It has been carried on at Lake Fusaro and other lakes in Italy from time immemorial, apparently from Roman days.

As far as has been determined, the elaborate culture of Italy with very particularly arranged bunches of twigs for collectors, preceded by a long interval the much simpler use of shells and similar cultch. Certainly it was the forerunner of the great development of oyster culture in Europe and America. As in many things, so in the antiquity of its oyster culture, China is supposed to rival Europe.

Essentially connected with this putting out of cultch is the maintenance of a supply of spawners, either by the strict maintenance of public beds, as has been the practice at Arcachon, France, or by the provision of

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proper private spawning beds, as in Italy and parts of England, and to a limited extent in some northern American oyster growing sections. Without one or the other of these, the use of cultch is at best a temporary success, and a very modest beginning. With either of these it represents the highest present development in oyster culture.[1]

Rakes, scoop nets, "nippers," and various implements have been used to various extents, but dredges and tongs are the important implements for taking oysters from the water. For the taking of oysters from the beds of continental Europe, Japan, Australia, etc., which are exposed at low tide, rakes, forks or shovels, according to the conditions, may be employed.

The dependence of the development of the oyster trade on transportation or on transportation and preservation, is obvious. In America, where the trade is and has been principally with opened oysters, this dependence has been of such a nature as to lead to very special means of handling and icing for shipment and to means of "permanent" preservation where transportation was inadequate or where, for any reason, prompt disposal of the entire crop was impractical or inexpedient. In some regions even yet (as Texas) the disposal of the crop is reported to be the principal hindrance to the further development of the oyster fishery. Canning has made possible the development of many an outlying fishery or one whose easily reached output was too vast for fresh consumption.

In America the development of canals and inland waterways, and later, and to a much more important extent, railroads, brought about an ever increasing trade and may be considered to have been the controlling factor in the oyster industry till the point was reached or approached where the supply was inadequate, and production instead of market became the great need, and oyster culture the center of attention.

In Europe the development of the oyster fishery, as it grew up after the downfall of the Roman Empire, was doubtless, in its earlier stages, a factor of the development of orderly society and of the consequent industry and commerce with interchange of ideas as well as material products. From a local seashore matter, we may assume, the use of oysters spread gradually to nearby trading points. Because of the large populations within small areas and the consequent small distances involved, and because the trade was then, as now, a "shell trade," the problem of preservation and speed of transportation did not loom as large as it has in America. However, development accompanying the establishment of steam-boating and railroading, is presumed to have carried the oyster trade along with it, and thus, by the middle of the nineteenth century, to have reduced the continental oyster supply to a point at which, if culture had not been developed, the industry would have perished.

Distribution of the Oyster Industry.

Not only is the oyster fishery one of the greatest of the world's fisheries, it is also of most remarkably wide distribution. Europe, Asia,

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[1] Full culture, such as the definite breeding of the European, *Ostrea edulis,* or the artificial fertilization of the eggs of the American, *Ostrea elongata* Solander (*Ostrea virginica*—synonym) and the rearing of the larvæ in vessels or enclosures (in spite of laboratory successes), is involved with so many difficulties as to appear very uncertain of commercial success in the near future.

Africa, Australia and the Americas, all have oyster fisheries, some of them along a wide expanse of coast. Europe and North America are the great homes of the industry. China and Japan in Asia, and New South Wales in Australia, have fisheries of special interest.

Oyster Fisheries of North America.

United States.[2]

The principal oyster fishery of America is that of the United States. This is the largest of all the oyster fisheries. From Cape Cod, in Massachusetts, to Florida and Texas, every state bordering on salt water has an oyster fishery of greater or lesser importance. The greatest of these are the fisheries of Rhode Island, Connecticut, New York, New Jersey, Maryland, and Virginia, Mississippi and Louisiana. Along the Pacific Coast, fisheries occur at various points north to Puget Sound. Although valuable in California and Washington, they are nowhere very extensive. The fishery may well be considered by states.

Massachusetts.—Wellfleet Harbor on the north shore of Cape Cod, Chatham along the eastern shore, and Cotuit Harbor and Poponesset Bay on the southern side, are the principal oystering areas in Massachusetts. Oysters are taken at a few other places on the coast.

Rhode Island.—The main oyster beds are in Narragansett Bay. The fishery is prosecuted from Providence.

Connecticut.—Although oysters are taken as far east as Stonington, the important fisheries are from Thimble Islands west, especially from New Haven west. The principal oyster grounds are in the open sound. Thimble Islands and the Norwalk Islands, and the Captain Islands, with the neighboring points of land partly enclose oyster growing areas. In the past, in this part of the coast, all the rivers in their lower stretches and all the bays and harbors contained naturally established and maintained banks or beds of oysters. New Haven harbor with its Quinnipiac River is the only one of these which is now an important oyster producer. The sound beds in the region of New Haven, Milford, Stratford, Bridgeport, and South Norwalk are deemed of special importance.

New York.—The principal oyster beds of the state are in Princess Bay, off Staten Island, and in the Long Island bays, notably Gardners Bay, the Peconic Bays, Great South Bay, Hempstead Bay, and Jamaica Bay. The harbors and bays along the north shore of Long Island and certain parts of the sound within the State also produce oysters to a limited extent. The principal oyster houses are in Greenport and West Sayville. Others are located at Suffolk, Jamesport, Patchogue, Northport, Oyster Bay, Freeport, East Rockaway, Inwood, various other points about Jamaica Bay, and on Staten Island. New York City is the great center of the oyster trade.

New Jersey.—Raritan, Barnegat and Great Bay along the coast, and Delaware Bay, especially the Maurice Cove section, comprise the main

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[2] This section on the distribution of the industry by states is based mainly on the section dealing with this subject in *Bureau of Fisheries Doc.* 890 (1920), by E. P. Churchill.

New Jersey oyster producing areas. Tuckerton, Keysport, Maurice River and Bivalve (the latter two on Maurice River) are listed as the principal oyster centers.

Delaware.—The oyster-beds of the state are located in Delaware Bay. The principal section is from Bombay Hook to below the mouth of St. James Creek, with Bivalve, N. J., as the principal shipping point.

Maryland.—The principal beds of Maryland are in Chesapeake Bay and tributaries, including Tangier Sound, and nearly all the bays and entering rivers from the Virginia line north to the mouth of the Patapsco River. This includes the Potomac River and a number of its tributaries. Chincoteague Bay, on the Atlantic side, is another important oyster producer. The other littoral bays to the north produce oysters to a limited degree. There are about 40 oyster houses at Crisfield, 28 at Baltimore (15 of them canneries), 25 at Cambridge, 15 at Oxford, 13 at Annapolis, 8 at Tilghman and 6 at St. Michaels; in all the State about 160. Besides the points listed is an oyster house at Benedict on the Patuxent River.

Virginia.—The Virginia sections of Chesapeake and Chincoteague Bays, with the important tributaries of the former and the bays along the Atlantic coast from Chincoteague south to the capes, comprise the oyster waters of Virginia. There are about 35 oyster houses in the State; 19 at Norfolk and Portsmouth, 2 at Hampton, 1 at Phoebus, 3 at West Point, 2 at Urbana, and others in Northampton, Middlesex, Lancaster and Accomac Counties. One of the finest oyster houses in the country is located at Hampton.

North Carolina.—Pimlico Sound contains far the greater part of the oyster grounds of the State. There are oyster canneries at Beaufort, Morehead City, Washington, Vandimere, Davis, Bay River and Sea Level (one at each place) and several shucking houses or "raw houses" (a southern term) at Wilmington and one at Newbern.

South Carolina.—St. Helena Sound and Port Royal Sound, in the southern part of the state, are the principal oyster producing waters. There are 5 canneries at Charleston and 6 at Beaufort, and a few at other points.

Georgia.—The oyster waters of Georgia extend along the entire coast line. St. Catherines, Sapelo, Do Boy, Altamaha, St. Simons, St. Andrews and Cumberland Sounds contain the principal oyster beds. Four of the fifteen canneries in the State are located at Savannah; the rest are scattered along the coast.

Florida.—Florida has a very large extent of oyster waters, but only a very moderate oyster business. The oyster waters embrace most of the numerous estuaries of the west coast of Florida. Far the greater part of the oysters come from Apalachicola Bay and adjoining waters and are handled at Apalachicola (locally known as Apalach), where there are several oyster canneries and "raw houses" (4 canneries and about 12 raw houses). St. Andrews Bay is said to contain many oysters and to have a considerable fishery in the North Arm of the Bay, carried on from Southport. Churchill states: "There is a small oyster business at Carrabelle and some beds at Cedar Keys. A few oysters are canned at Fernandina, . . ." Oyster beds have been reported from St. Johns River. Doubtless oysters occur in others of these east coast Florida waters.

Alabama.—The oyster producing waters of the state are the Alabama section of the Mississippi Sound and the lower part of Mobile Bay. Most of the oysters are handled through Bayou Labatre where a cannery is located. There are a number of dealers in Mobile.

Mississippi.—Although Mississippi possesses oyster beds, located principally in Mississippi Sound, it is dependent for its large cannery and considerable raw shipping trade upon Louisiana waters.

Churchill lists Biloxi as having 12 canneries (a greater number than any town except Baltimore), and six "raw houses," and Gulfport, Pass Christian, Bay St. Louis and Ocean Springs as having one cannery and one or two houses each.

Louisiana.—The principal oyster producing waters of the state are in St. Bernard Parish (eastern side). Others are Barataria Bay and the estuaries of Plaquemines, Terrebonne and the coastal parishes to the westward. Churchill credits New Orleans with about 24 wholesale oyster dealers and lists the canneries as located as follows: 1 at New Orleans, 2 further down the river, 2 or 3 at Houma in Terrebonne Parish, and a new one just starting in Franklin.

Texas.—Galveston, West, Matagorda, Savaca, Espiritu Santo, Mesquite, Aransas, and Corpus Christi Bays are oyster producing waters. Corpus Christi, Port Aransas, Rockport, Port O'Connor, Port Savaca, Seadrift, Palacios, Matagorda and Galveston have from two to six shucking houses. Unless one has been very recently established, there is no oyster cannery in the state.

West Coast.—The comparatively small oyster industry of the west coast, concerned with the native oyster, *O. Lurida,* Carpenter, and with Atlantic Coast oysters grown from seed, shipped across the continent, centers in San Francisco and Tomales Bays, California; Yaquina River, Oregon; and Willapa Bay, Washington.

Canada.

The principal oyster fishery of Canada is that of the region about the mouth of the Gulf of St. Lawrence, whose warm waters temper those of the North Atlantic. New Brunswick and Prince Edward Island yield the greater part of the oysters, Nova Scotia a much smaller part. The oyster is the same, specifically, as that of the United States Atlantic Coast.

British Columbia has a small oyster fishery in Puget Sound. The native oyster, *O. Lurida,* Carpenter, is the same as that of the west coast of the United States. Attempts have been made to introduce the eastern oyster.

Mexico—South America.

Oysters occur scatteringly from Texas and California to Uruguay (perhaps farther) and southern or south central Chili. Although fisheries of a sort are carried on along some considerable portion of these coasts, in few places do they attain considerable proportions or lose a decidedly local character. In general, the chief fisheries are located in the neighborhood of the larger cities or where transportation to inland cities or more distant coastal points is specially facilitated. Limited exportation occurs from one or two countries. In a few places where the trade has made such action profitable, oyster beds have been established. In general, the oysters are obtained from natural beds by diving or by other similarly primitive methods. Oysters are shipped in the shell or, where cities afford an artificial supply of ice, shucked and iced. In a few places oysters are salted and dried. Canning has been tried in a small way but not established. Where the qualities, quantity, and location of oysters are sufficient, this method may lead to considerable developments in oyster fisheries, for slow transportation and difficulty in preservation are important present factors against such expansion. Oyster fisheries have been definitely reported from Mexico, Panama, the West Indies and South America.

The commercial oyster of the east coast of Mexico is *Ostrea elongata* Solander. Other species occur as in southern United States, but are believed not to be of commercial importance. On the western coast, including the Gulf of Colon, *Ostrea columbiensis*, Hanley, is the principal, if not the only, commercial species. Other species of good size occur but perhaps chiefly because of crenelated shell margins, which make opening difficult, are used very little.

On the east coast of South America various forms occur. Of these it is believed that *Ostrea puelchana* is of chief importance. Two west coast species of commercial importance are reported, *Ostrea columbienses*, Hanley, and *O. chilensis*, Philippi.

Europe.

The principal oyster fisheries of Europe are those of France, the British Isles, Holland and Italy. Other countries which have, or in recent years have had, lesser fisheries, are Spain, Portugal, Belgium, Germany, Norway, Sweden and Russia. Presumably local fisheries occur in Mediterranean countries not included in this list.

France.—The oyster industry of France is notable not only for being the greatest in Europe, but also for its high development, and more especially for the fact that this great industry, as well as that of much of the rest of Europe, is largely supplied with seed oysters collected at two localities by highly artificial means involving great expenditure of hard labor. Specialization has been carried to a high degree and has been very successful. The Bay (or Basin) of Archachon, near the north border of Gascogny, and the Gulf of Morbihan on the south coast of Brittany, with their tile spat collecting, are the great seed producing waters. Marennes and la Tremblade, south of Rochefort, with their oyster ponds or "claires," are the most famous for rearing and conditioning of oysters. Another well known place is Cancale on the Bay of St. Michel (north coast of Brittany).

Great Britain and Ireland.—The principal fisheries are those of England, of which the chief, both in regard to quantity and quality, is that of the Thames estuary. Whitstable, one of the most famous oyster centers in the world and the principal seat of this fishery, markets over half of the oysters of England and Wales. Important oyster towns on the north or Essex side of the Thames are Brightlingsea, on Colne River; Tallesbury, on Blackwater River; Burnham, on the Crouch River; and Paglisham, near the River Roach. These supply much "seed" or "brood." The next important fishery is that of the waters about the Isle of Wight, from Chichester Harbor to Poole Harbor. Basham, on Chichester Harbor, and Poole, on Poole Harbor, are the leading oyster towns. Ensworth and Warsash also handle considerable quantities of oysters. The third in importance of English oyster fisheries is that of the Fal and Halford estuaries, with Falmouth and Truro oysters relaid in Helford River and handled through Helford Passage. Mumbles, near the mouth of Swansea Bay, Wales, handles nearly as many oysters as Helford Passage; Yealm, whose harbor opens near the mouth of Plymouth Sound, about half as many.

The Thames estuary, especially the south shore, is famous as a growing and conditioning area and produces the most highly prized "natives." Considerable "falls of spat" occur, but not sufficient to supply the demand. "Sets" or "falls of spat" occur in this and in greater or less amounts in most of the oystering sections. In the past, great quantities of French "brood" or "seed" oysters have been imported. The official statistics of imports would indicate that this practice has stopped.[3]

The oyster fishery of Ireland is small compared to that of England, and depends chiefly upon the public beds in the neighborhood of Wicklow, Queenstown, Ballyheige, Galway and Moville; that of Scotland is still smaller and centers about Inverary and Ballantrae.

Holland.—The oyster fisheries of Holland are very highly developed and nearly as important as those of England. The most famous of the Holland fisheries is that of the Scheldt, where spat are collected on specially arranged tiles and, in general, the most is made of the territory and opportunities. The oysters have a great reputation for excellence. Although the grounds are all private, it has been held that the state maintains beds of spawners by preventing dredging along the dykes.

Other European Countries.—Italy is the only other European country possessing an important oyster industry. Here oyster culture has been carried out since Roman times. Italy's annual production is probably less than 100,000 bushels. Some oysters are also produced in Spain, Portugal, Belgium, Germany, Denmark, Norway, Sweden and Russia.

Asia.

China.—The oyster fishery of China, believed to be one of the oldest, if not the very oldest well developed oyster fishery in the world, is said to be extensive and well maintained. Apparently there is a fishery along the coast, especially in the river mouths, from Shantung Peninsula south. Shantung Peninsula, the mouths of the Yangtze and Ningpo Rivers, the coast of Fukien, and the neighborhood of Namoa Island, have been mentioned as of notable importance.

Japan.—The oyster fishery of Japan, although not one of the most extensive, is, because of its special and high development, one of the most famous of oyster fisheries. The Inland Sea is the seat of the principal fishery and of the oldest oyster culture in Japan. Oysters are also taken from various bays, particularly of the northeast coast of the main island, but also to the north in the island of Hokkaido, in Kiusiu Island, and in Tokyo Bay, midway between these extremes.

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[3] *Fisheries—England and Wales—Sea Fisheries—Statistical Tables, 1921.*

The principal oyster of Japan, *Ostrea cucullata*, is about the size of a "Bluepoint" or an English "Native." Besides that of Japan proper, an oyster fishery in Formosa has been developed.

India and Neighboring Asia.—Natural oyster beds are stated to be both numerous and widely distributed in the estuaries of India. The chief fisheries of the west coast are those of Tellicherry and Beypore in Malabor; Cochin and Azhipode in Cochin, and Vembanad backwater in Travancore. Oyster producing waters of the east coast are Cuddalore, Covelong, Enner and Pulicat backwaters, the deltal estuaries of Kistna and Godavari and, to the north, the various backwaters of Vizagapatan and Ganjam, especially Sonapur backwater. The government has managed a model oyster bed in Pulicat Lake.

Africa.

The oyster industry in Africa is nowhere a large one. In Algeria there has been a limited amount of bedding of imported oysters. In Cape Colony, along the southern coast to the east of the Cape, a fishery for the small rock oysters is stated to have been carried on for many years by the poorer people. An excellent oyster is reported from Natal. Past attempts at cultivation and at the introduction of European oysters have failed. Doubtless in many other places along the African coast local oyster fisheries occur.

Australia and New Zealand.

Although oysters are said to be grown in various parts of Australia, it is only the New South Wales industry that has attracted much attention. There, especially in Georges River, successful and highly elaborate oyster culture has been developed, in spite of many difficulties.

The oyster industry of New Zealand, at least up to recent years, has been carried on chiefly from Auckland northward. Attempts have been made to introduce the oysters further south.

Philippine Islands.

Although it does not appear that there is an industry of any importance with the edible oyster in the Philippines, it is stated[4] that oysters are "among sea products which can profitably be exploited."

Statistics.

As has been already stated, the oyster fishery is one of the greatest fisheries in the world. Shore waters of every continent and of some 35 countries contribute to its total. Although with the ever growing demand of recent years the supply, partially maintained by the extreme fecundity of the oysters and, in a number of important instances, by cultural methods of the various sorts, has dwindled, the decrease in quantity generally has been counteracted by the increase in price.

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[4] *Commerce Reports* (*U. S.*), 1921, No. 147, 1751.

The World's Oyster Industry.

Statistics in this, as in any great fishery, are at best only approximate. The crop is apt to vary much from year to year, aside from a general decrease. Encyclopedia Britannica[5] estimated the world's oyster crop in the closing years of the last century to be a little under 31 million bushels, with a value of about $18,500,000. The production of oysters at the present day is certainly less than this. Instead of the nearly 27 million bushels, the United States would now contribute to the total about 17 million bushels (market oysters). England and Wales also would contribute decidedly less (about two-thirds as many in 1922 as in 1899). Recent figures for other oyster producing countries are not at hand, but the 1912 figures of over 2,000,000,000 oysters for France would indicate that production is not falling off in the only country except the United States which attains to large figures.

Doubtless, for the purpose of this large scale estimate, it is reasonable to assume that 5 million bushels will be sufficiently high for foreign production, and that 22 million bushels is a reasonable approximation of the world's annual production of market oysters. Because of the increased price, the total value of the world's crops, instead of decreasing to a marked degree, probably has increased somewhat. The American crop has about maintained its value, that of England certainly has increased in value, as presumably has that of France (about 27,000,000 francs in 1912 against 18,000,000 francs in 1896) and have those of other countries. Without allowance for the present day complicated state of exchange, the value of the world's crop of marketable oysters (as opposed to "seed" or "brood") may therefore be taken to be between $20,000,000 and $21,000,000. This estimate does not take into consideration the value of the shells. Over 100,000 people are engaged in the oyster industry, and many millions of dollars are invested therein. In the United States, the value of shells crushed for poultry food is over $2,000,000.

The production of England and Wales in 1916 was 39 million oysters, or considerably above pre-war figures, and even above those of 1898. In 1921, it had fallen to 31,027,044 oysters (value £207,909), and, in 1922, to 23,602,273 (value £176,789).

United States.

The total production of market oysters, according to the latest statistics of the U. S. Bureau of Fisheries, and with deductions for seed oysters, is 17,176,163 bushels, with a value of $12,618,135. By states this is divided as follows:

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[5] Encyclopedia Britannica, Cambridge, *20*, 1911, 425.

TABLE 63

Production of Oysters and By-Products

Oysters

State	Bushels	Value
Massachusetts (1919)	110,662	$ 279,547
Rhode Island (1919)	894,537	1,242,585
Connecticut (1919)	709,046	493,666
New York (1921)	1,346,210	1,775,453
New Jersey (1921)	1,578,165	2,070,496
Delaware (1921)	401,826	368,115
Maryland (1920)	4,547,471	2,291,120
Virginia (1920)	3,225,844	2,167,923
North Carolina (1918)	216,962	70,280
South Carolina (1918)	397,690	96,542
Georgia (1918)	158,546	73,913
Florida (1918)	439,276	141,948
Alabama (1918)	120,243	38,175
Mississippi (1918)	1,272,389	307,326
Louisiana (1918)	1,122,203	494,299
Texas (1918)	477,784	143,610
California (1915)	54,887	172,086
Oregon (1915)	221	725
Washington (1915)	102,201	390,326

Canned Oysters in 1922

State	Number of Cases	Value
Maryland	80,872	$ 479,572
North Carolina	29,000	121,067
South Carolina	119,897	511,865
Georgia	18,812	85,371
Florida	14,034	66,425
Alabama	39,297	171,707
Louisiana and Mississippi	220,637	987,609
Total	522,549	$2,423,616

By-Products in 1922

States	Crushed Shells		Lime	
	Tons	Value	Tons	Value
Rhode Island, Pennsylvania, and New Jersey	20,493	$ 200,831	7,799	$ 31,873
Maryland	90,249	803,388	382,106	155,119
Virginia	26,173	230,115	27,445	182,680
North Carolina, South Carolina, and Georgia	6,740	56,165	1,815	9,075
Florida	13,800	96,400	112	1,008
Alabama	7,154	56,987	510	760
Mississippi	32,646	251,872	780	780
Louisiana	34,684	274,944	15,956	47,218
Texas	4,082	35,136	540	2,700
	236,021	$2,005,838	437,063	$431,213

The Growing of Oysters.

Life History.

The oyster resembles other lamellibranch mollusks in that it possesses a two-valve shell, secreted by a "mantle" which lines the shell and surrounds the fleshy parts, breathes by means of gills, feeds by straining out minute organisms (plankton) and particles of vegetable matter (detritus) from a relatively large quantity of water which is drawn in by means of ciliary wave movement. It differs from most of them in that after the larval stage is passed, it no longer possesses the power of movement. Wherever it "sets" there, unless man comes to its aid, it must remain, no matter how unfavorable the location proves, how sure and early the destruction.

Oysters are highly prolific, a large female of our east coast species (the sexes of which are separate) is estimated to develop annually some 60 million eggs about .05 mm. in diameter. When water temperatures are high enough and rising and when conditions are otherwise favorable, spawning may be very vigorous and a third or more of these vast numbers of eggs thrown out at one spawning. Particularly is this true in the more northern waters. Sperm are slender with a head about .0025 mm. in diameter, and a thread-like tail about .05 mm. of an inch long. These sperms, almost inconceivably numerous, are believed to be produced by billions per individual per season. They swim until they come in contact with an egg. In a few hours after fertilization of an egg, a swimming embryo is developed. Then shell valves are formed, which gradually spread over the body until it is covered. Nearly concurrently with this development of a fully surrounding shell the "egg yolk" is exhausted and the embryo changes to the larva. This occurs variously from 24 to possibly 48 or even more hours after spawning. The larva is then about .06 mm. in greatest diameter and somewhat clam-shaped, but with rather a long, straight hinge line. It possesses a ciliated velum which acts effectively as a swimming organ. As the animal grows, its left valve, which in the adult is to be the lower valve, increases in proportion to the right valve and the straight hinge line is lost. This stage lasts about two weeks, at the end of which time the larva is about .33 mm.[6] in greatest diameter. It then attaches itself, if fortunate enough to find it, to an old shell, piece of gravel or other suitable object. This is known as "setting" or "striking."

From the small "spat" or "set" stage, the oyster develops into a "seed" oyster, and then, generally in four or five years, into a market oyster. Spawning may occur with one year old individuals, but whether effectively or not is not known. Growth is more rapid in some southern waters.

The European oyster differs from that of our east coast, in that it is hermaphroditic, and in that the larvæ are held to an advanced stage in the gill chamber of the adult. Normally fertilization occurs in the oviducts by sperms from another individual. Our west coast species is hermaphroditic, and the young are retained much as in the European oyster.

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[6] This varies with the locality. The measurement given applies to Long Island Sound larvæ.

Factors of Environment.

General Habitat and Distribution.

Ostrea elongata Solander (or *Ostrea virginica* Gmelin), the east coast oyster of the United States, is a brackish water form; although it will survive in water closely approaching both ocean saltness and complete freshness, it thrives best in water of a salinity approximately represented by a range of specific gravity from 1.010 to 1.022. Decidedly, it is a temperate to tropical species. Although it will survive the severe winters of southern New England and eastern Canada, it will only reproduce where a water temperature of approximately 70° F. or more is maintained through a period in the summer. Thus, we find that it occurs naturally from the Gulf of Mexico to Cape Cod and again to the north in the comparatively warm waters at the mouth of the Gulf of St. Lawrence. In this vast stretch of coast, its natural home is in the bays or smaller estuaries or just off the mouths of these.

Food and Feeding of the Oyster.

For many years it has been known that the oyster feeds by straining out plankton organisms and finely divided vegetable matter (detritus) from the water. At various times it has been held that the food consisted almost wholly of diatoms or of detritus. Recent investigations indicate that salt or brackish water diatoms, animal plankton and detritus all play a part, but that the most important part is played by those ultra minute forms which are termed the nannoplankton.

It has been shown that oysters feed a large part of the time[7] and that a feeding oyster "filters" many gallons of water a day. Oysters, therefore, are able to exist where food is relatively scarce if conditions are otherwise favorable.

Salinity.

As has been stated, the oyster is a brackish water form which thrives best in water of a range of salinity represented by variations in specific gravity from about 1.010 to 1.022,[8] although it will survive in water somewhat more dense than this upper limit, and considerably less dense than the lower. Rapid changes in either direction, however, are unfavorable. Extreme freshening sometimes works serious havoc.

Trade Wastes.

More and more, as industry develops, manufacturing wastes of various sorts, including dyes, metallic salts, and acids are being discharged into the estuaries which make up so large a part of the natural home of the oyster. As these discharges increase, these natural oyster regions are being made utterly unfit for oysters. Although oyster culture, by finding new grounds and making the most of the available "seed," helps to stem the tide, it seems that its battle must be a losing one unless something is done to curb the waste discharges or great improvement is made in culture.

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[7] Nelson, T. C., Report Dept. of Biology, New Jersey Agricultural Experiment Station, New Brunswick, N. J., 1920.

[8] It is generally held that 1.007 is the lower limit for culture. The author has obtained readings of 1.023 where oysters were grown successfully.

Silt.

The presence of large amounts of suspended matter in the water is not helpful to oysters. It has been held that it will prevent oysters from feeding. Even if this is not the case, it seems scarcely to be doubted that it will increase the work of feeding or decrease the food secured. However, the principal evil lies in the silting of the bottom. Where this is extremely heavy, it may even wipe out beds of adult oysters. More moderate deposits will smother the very small oysters or make elongate, silt-avoiding "coon" oysters of those that survive. In still less abundance, it coats shells and other cultch and makes the attachment of the spat more difficult.

Bottom.

The character of the bottom is very important for the growing of oysters. Too soft a bottom will allow the oysters to sink and smother. A shifty sand bottom will cover and so destroy them. A bottom with a high organic content may generate poisonous organic gases in sufficient amounts to be harmful. A moderately stiff to hard bottom is necessary. On a rocky bottom oysters may do finely. The trouble is to secure them. Of course no bottom for oyster growing should be exposed to the strong action of waves or the air of northern winters, or be too far below the surface for practical working.

Enemies.

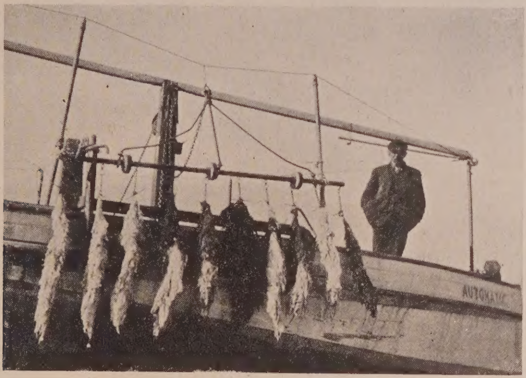
The active enemies of the oyster are chiefly those which prey upon the young. Larvæ undoubtedly are consumed in immense numbers by plankton feeders. Boring mollusks, especially the oyster drill (*Urosalpinx*), starfish, and some fishes prey disastrously on the spat. Although adults are killed by starfish and the larger borers, losses of this sort are comparatively small.

Spat Collecting.

Nature's spat collectors are the shells of oysters or other mollusks, either dead or alive, rocks, gravel, submerged roots or other suitable objects. Man employs some of these and some of his own designing. In Europe, Asia, and Australia, many special spat collectors are employed. In America, up to the present time, only shells (principally oyster shells) are used to an important extent. These are put down, some hundreds of bushels per acre, as little before the setting time as experience indicates may be safely done. Because in any locality the time of setting varies, it is generally necessary to finish the planting considerably before setting occurs.

Moreover, with large companies "shelling" may take about a month. Therefore, many of the shells will have been down a considerable period, and become considerably fouled. Unset shells may be taken up, dried and replanted another year, or, less satisfactorily, left down and "stirred up" with dredges near the setting time. Brush spat collecting has been tried to a very limited extent in this country. Where the bottom is unsatisfactory, it offers definite advantages.

As is pretty well understood in Europe, but only beginning to be appreciated in this country, the first essential to securing spat is a sufficient and properly located supply of healthy adult oysters for spawners. Care should, of course, be taken to select a setting ground not over-run with starfish or drills, or to remove these by dredging and "mopping."



Courtesy U. S. Bureau of Fisheries.

Fig. 180.—"Mop" or "tangle" installed on oyster boat. This is dragged across starfish infested beds with such effectiveness that great numbers of this pest become entangled in the loose threads. They are killed by the immersion of the mop in boiling water.

In general in European and Asiatic countries, special spat collectors are employed. These range from the cemented tiles of the French and Dutch through the stones of the Chinese to the brush and bamboo collectors of the Italians and Japanese. Good accounts of these methods may be found in the writings of Dean and of Mitsukuri. England differs from other important old-world oyster-growing countries in that it uses shells for cultch essentially as is done here.

Growing and Conditioning.

Although in some localities it is sufficient to secure a "set," in general, this only means the beginning of the work of growing oysters. Frequently the best "sets" occur in regions or on grounds where drills, starfish or other enemies or destructive agencies are prevalent or where growth is poor. In the latter case, the seed oysters may be shifted that fall or sometime during the next year. If it seems that only shifting might save a high percentage of a valuable "set," this would be done as soon, presumably early in September, as handling of the spat seemed safe.

On the growing ground, one crop of oysters may remain three years or more before being transplanted to a fattening or conditioning ground. On the other hand before that is done it may be shifted once, twice or even more times, for culling and breaking up bunches more nearly into single oysters, cleaning of the grounds, etc.

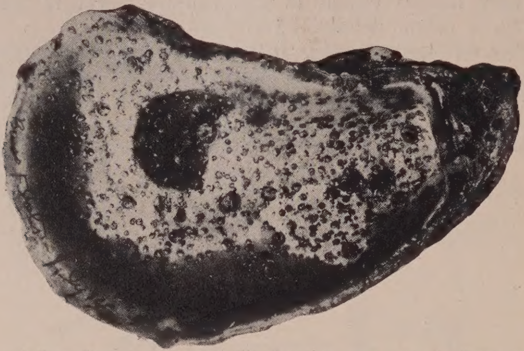


FIG. 181.—A heavily set oyster shell, showing spat one to three weeks old.

The conditioning ground may be chosen for actual improvement in flesh, for improvement in flavor, or even that the oysters may be marketed by a famous name given to oysters from a certain locality. They may be kept there for any period, for three months, or less, to a year.

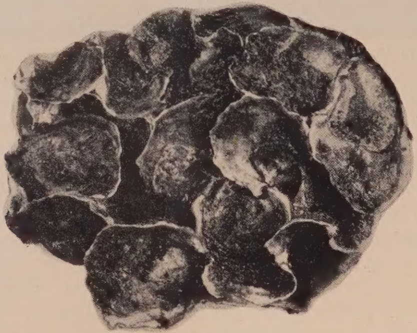


Photo by H. F. Prytherch.

FIG. 182.—A cluster of one year old oysters still attached to cultch.

"Floating" oysters, or placing them in slatted "floats" in relatively fresh water, is a process especially employed with oysters to be used in the shell trade. With oysters for this trade, in which no increase in bulk is obtained, the sole purpose of this floating is to enable the market men to keep the oysters in good condition for a reasonable length of time.[9] For the shell trade, therefore, if the floating be done in sufficiently pure water no objection can be raised.

Taking Oysters from the Beds.

In this country there are in use two important methods of taking oysters: dredging and tonging. Tonging is employed on certain public beds and by planters in smaller bodies of water or in water of little depth. Although experts sometimes make large daily catches by this means it cannot compare in rapidity with dredging, especially where oysters are not very abundant. Its advantage lies in the small capital outlay for equipment and its adaptability to restricted operations. Tongs vary in length from twelve feet to over twenty, according to the depths of water in which they are to be used. They are long scissor-shaped instruments, with toothed iron baskets fitting together at the tips. The long wooden handles are an inch thick and three to four inches wide at the hinge point (about four feet from the end, but varying with the length of handle) and taper toward each end. They are riveted, bolted or pinned together. The toothed iron baskets which catch and hold the oysters are as much as three and a half feet long and ten inches wide. Ordinarily they are worked from flat-bottomed skiffs, "bateaus," or something of the sort.

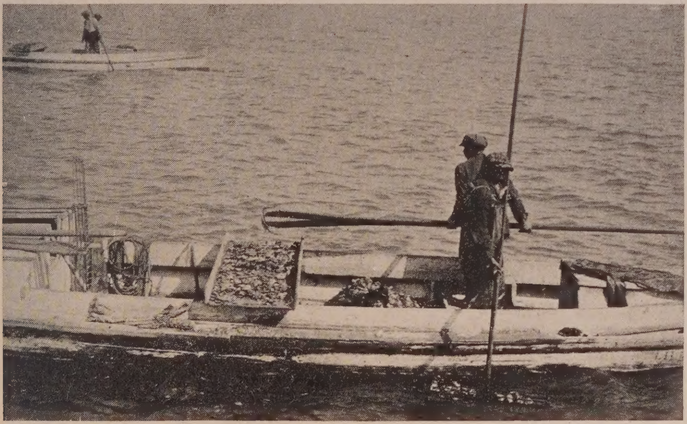


Photo by E. C. Cory.

FIG. 183.—Tonging oysters in the Chesapeake Bay.

Besides these hand tongs, what are known as "patent" tongs, or "deep water" tongs, have been used in the deeper waters of the Chesapeake. These are constructed much as are the hand tongs, but with shorter "handles" of iron with holes in the upper end for the ropes by which the

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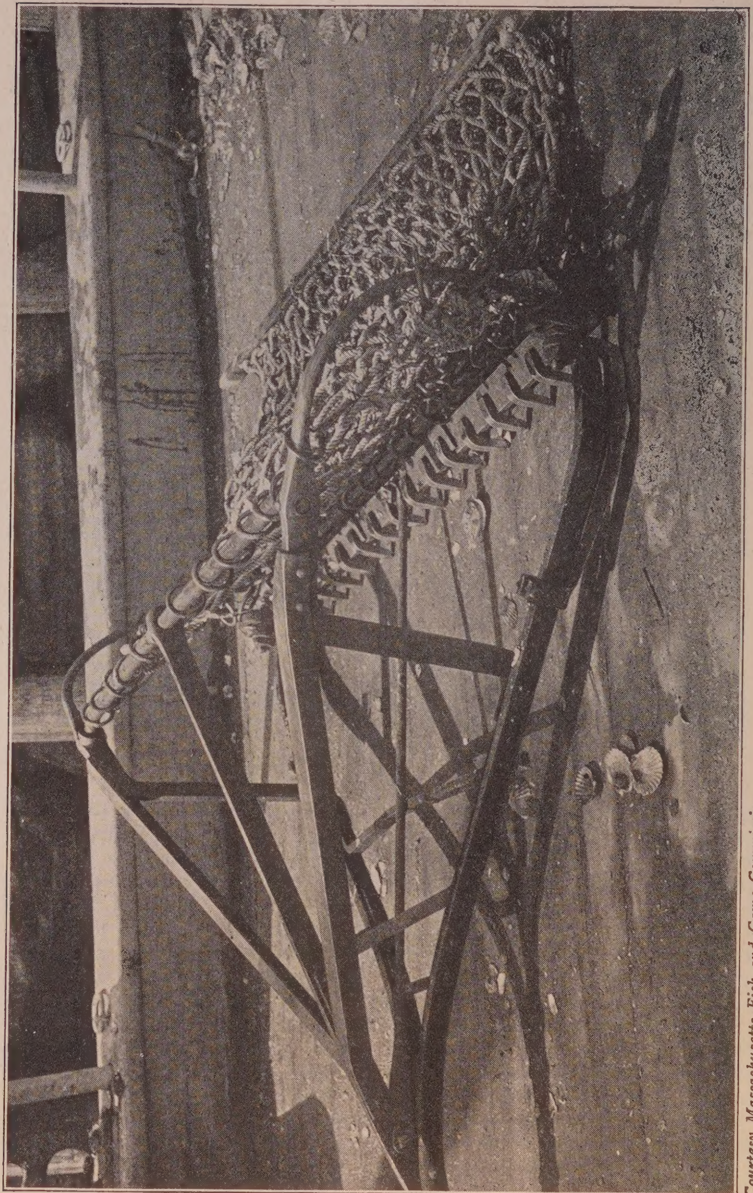
[9] That floating serves this purpose there seems to be no doubt. Whether the explanation is to be found in the clearance from the mantle chamber of fœces and palpal rejections, as Nelson suggests, in extra water storage in the tissues, as the author has supposed, or in both, remains to be shown.



Courtesy Massachusetts Fish and Game Commission.

Fig. 184.—Typical medium-sized oyster dredge commonly used on gasoline-driven oyster boat.

tongs are lowered, "worked" and raised. A hook on each handle engages the baskets of its mate, while the tongs are being lowered and releases it at the bottom. A windlass and derrick arm are employed with this type of tong.

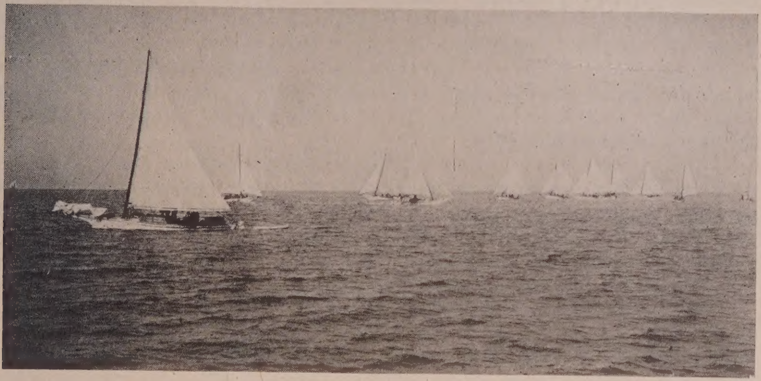


Fig. 185.—A fleet of small southern sail boats, of the type known as "skipjack," at work dredging for oysters.

American oyster dredges generally consist essentially of two iron isosceles triangles united at the tips and spread moderately at the bases from which a bag is suspended. One of the triangles is made as open as practi-

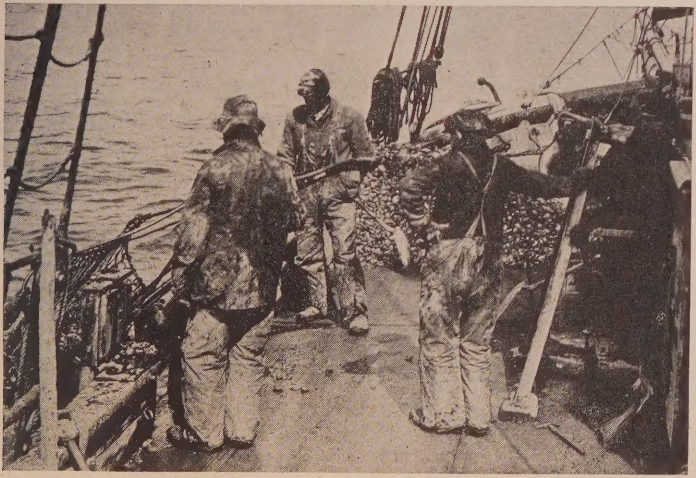


Photo by E. C. Cory.

Fig. 186.—Hauling a loaded dredge by means of the "donkey" engine of a large sail dredge-boat.

cable, and possesses, at the base, a blade which generally is toothed. This is the lower half of the dredge and to it, at the base, is attached the lower iron-meshed half of the bag. The upper half, or side, of the dredge, which may, without harm, be braced for strength, holds at its base the upper or twine half of the dredge bag. A curved bar on each side of the dredge at the base keeps the two iron frames apart. Additional bracing may also be given. Small hand dredges are single framed. Sometimes a "cutting board" is employed to hold the dredge to the bottom. The closed end of the bag is attached to a stick.

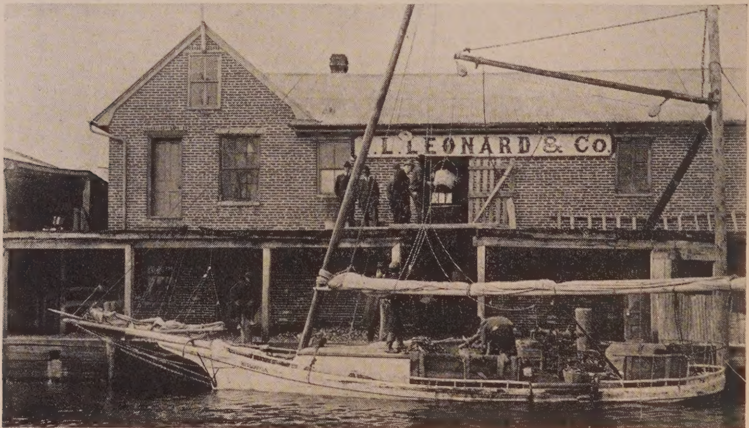
Dredges vary in size from light hand dredges with a capacity of two or three bushels, up to the huge dredges of approximately thirty bushels capacity, employed in Long Island Sound. According to the size or legal restrictions they are pulled directly by hand, by hand windlass, by donkey engine, or by the power machinery of the dredge boat. The very largest are dumped by machinery; all others by hand.

The dredge boats vary from small sloops, "skip jacks," sharpies, etc., to the large steam vessels of the northern industry, the largest of which works six big dredges and has a daily capacity of about 8 thousand bushels per day. These larger steamers are housed in so that the crew works in comparative protection from the elements.

In use a dredge is dragged out behind a boat, going at reduced speed, until it is supposed to be full, then hauled in and dumped on the deck or possibly in the hold. All but the smaller dredges are drawn in over an iron roller with a nearly vertical roller at its after end for further protection of the dredge rope.

Unloading the Oysters.

Ordinarily oysters are taken by means of bucket and hoist from the deck or hold of the oyster boat onto the wharf itself, or directly into the



Courtesy U. S. Bureau of Fisheries.

FIG. 187.—Unloading oysters by hoist directly to the upper story of an oyster house, later to be conveyed as desired directly to the tables of the shuckers.

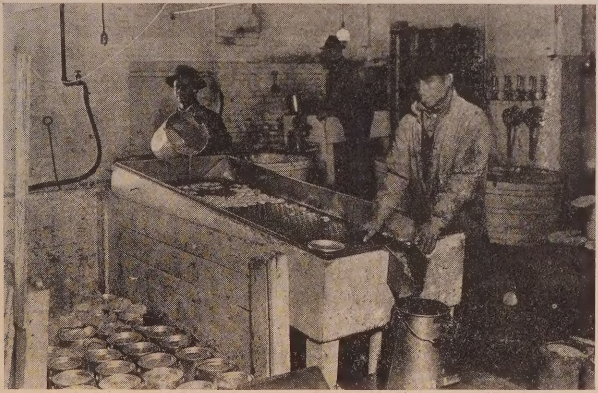
large, steel wheelbarrows in which they are to be conveyed into the oyster house. A few of the larger houses are so arranged that the oysters can be hoisted directly to the upper story; thence to go by means of chutes, or endless conveyor and chutes, to the culling or shucking bench of the workmen. At one very large house endless belt conveyors have been installed for taking the oysters from the boat and raising them into the upper story. Oysters have been taken from the very largest steamers by means of horse and wagon. If the quantity involved is small or if more convenient means are not available, oysters may, of course, be unloaded in baskets or by wheelbarrows.

In Europe, with the high-priced product, the comparatively small quantities involved and the general cheapness of labor, very different methods are employed.

Marketing Raw Oysters.

Shucked Oysters.

In this country the principal business is in raw, shucked oysters or oyster "meats" removed from the shell. These oysters are opened or "shucked" by highly skilled workmen known as "shuckers." They work at benches, generally iron shod, and open the oysters by means of oyster knives. Some shuckers crack the thin ends or "bills" for the insertion of the knife. Others open with a knife only, which they thrust between the shells at the side or at the thin end. It is said that those who first crack the shells cannot make the extreme speed of the others, but are able to maintain a better pace. The knife cuts the large adductor muscle and thus enables one shell to be removed. Another cut through this same muscle quickly removes the body of the oyster from the other shell and into the perforated oyster measure. 10 to 12 gallons a day is said to



Courtesy U. S. Bureau of Fisheries.

Fig. 188.—Washing the opened oysters or "meats."

be an average day's shucking, although this amount may be greatly exceeded. Good oysters will shuck 6 quarts of meats per bushel.

After being shucked, the oysters are washed first on a perforated table, a sloping transversely corrugated "riffle" board, or some similar means, and later in galvanized tanks, to which they may be conveyed through troughs by running water, and where they are very thoroughly washed with a change of water and sometimes with aeration. Ordinarily all this washing is in tap water. To prevent the swelling or "dilution" which may result from this practice, regulations sometimes require the addition of salt to the water.

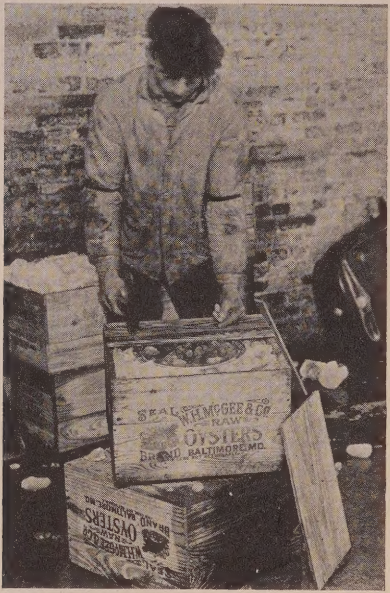


Photo by E. C. Cory.

Fig. 189.—Packing a tin of opened oysters in ice preparatory to shipping.

After being washed the oysters are graded according to size into "standards" and one or more larger sizes. The most commonly known of these are the "selects." If four grades are made, these generally are known, from the smallest to the largest, as "standards," "selects," "counts," and "extra selects." They are then placed, well drained, in containers of some sort, which in turn are packed in ice and so shipped. The most commonly used form of container is a "non-returnable" tin can of 1, 3 or 5 gallons, with a tightly fitting top. Small bottle containers and sealed tin cans are also employed.

The shells are taken by some type of conveyor to the shell pile which may be very large.

Shell Stock.

Ordinarily only the more choice oysters or those from waters famous for the quality of their product are marketed in the shell. These oysters are mainly for the hotel and restaurant trade, to be eaten "on the half shell." Great fame attaches to oysters from certain localities. The most famous of these are the "bluepoints" from Great South Bay, and taking their name from Blue Point on its northern shore. Typical "bluepoints" are small and well rounded. They are of medium saltness and possess a very delicate flavor. Of course oysters from many places may be served as "bluepoints."

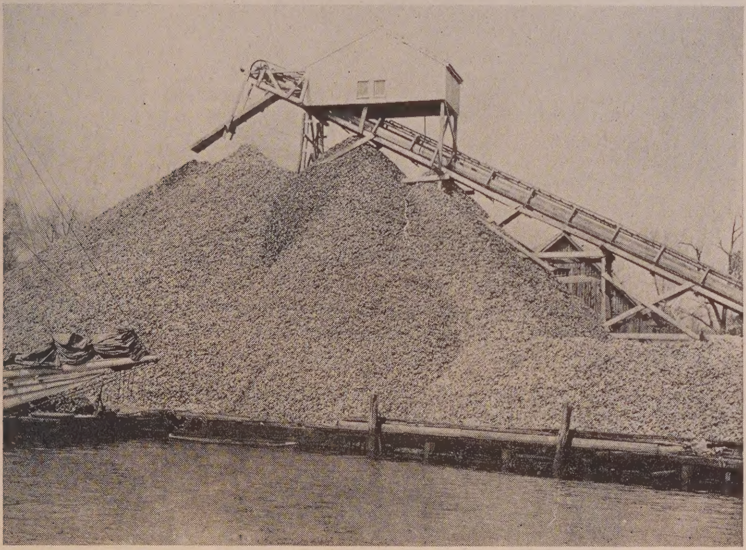


Photo by E. C. Cory.

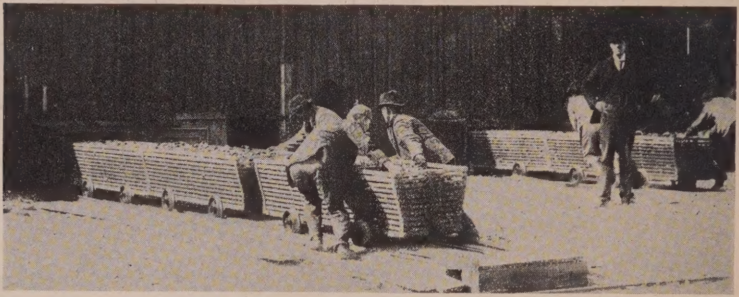
Fig. 190.—A large pile of oyster shells under the conveyor that brought them from the shucking room.

"Cotuits" from Cotuits Harbor, Mass., or nearby waters, are larger and more pointed. Other well-known "brands" are "Maurice Rivers" from Maurice River Cove, and the immediate neighborhood in Delaware Bay, N. J., "Lynnhavens" from Lynnhaven Bay, Va., "Chincoteagues" from Chincoteague Bay, Va., "Cape Cods" from the northern shore of Cape Cod, Mass., and "Rockaways" from Jamaica Bay, L. I. The last three of these include oysters of the decidedly salty flavor which is preferred by some. The vicissitudes of the oyster industry threaten to do away with some of the famous "brands."

Oysters in the shell ordinarily are shipped in three bushel barrels. Half barrels and sacks sometimes are used. Frequently the barrels are covered with burlap instead of being headed. For short or moderate shipments no chilling is employed. Long shipments are made in refrigerator cars or in the "cold room" of vessels. In this way oysters may be shipped across the continent or to Europe. The most satisfactory temperature for storage seems to be a few degrees above freezing, perhaps 36°-38° F.

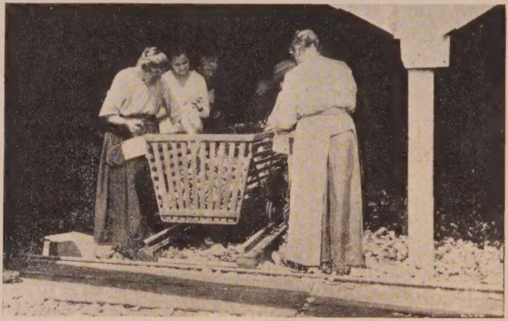
Canning.

The practice of canning oysters is almost, if not quite, wholly American. As previously explained, it developed as a means of extending the market and overcoming the difficulties in storage and transportation. The first canning of oysters occurred in Baltimore, Md., in 1820. The name "cove oysters," which came to be attached to canned oysters, originated in the fact that in the early days the oysters for canning were secured from the various coves of the western Chesapeake shore, north of the mouth of the Potomac. Of recent years, there has been a great



Courtesy U. S. Bureau of Fisheries.

FIG. 191.—Slatted iron cars, loaded with oysters, being pushed into the steam room of an oyster cannery. A brief steaming kills the oysters and enables easy opening.



Courtesy U. S. Bureau of Fisheries.

FIG. 192.—Opening oysters which have been through the steam room.

increase in oyster canning in the more southern states where transportation and market problems still present difficulties. Biloxi, Mississippi, has come to rival Baltimore itself.

At most of the large canneries, the oysters are unloaded directly into latticed iron cars 10 to 12 feet long. These cars are pushed, sometimes three at a time, into a large steaming room or "steamer" in which the oysters are steamed 3 to 10 minutes or until killed. They are then pushed on through into the opening room. Because the shells of the steamed oysters have opened, it is comparatively easy work to remove the meats with the usual oyster knife. This is done directly from the cars and into perforated buckets. The "meats" are then washed and packed to weight in cans varying in size from 3 to 10 ounces. By an endless belt, the filled cans are conveyed to capping machines of either the crimping or soldering type. After being capped, the cans are conveyed in large iron baskets to the retort, where they are steamed at a high temperature for a short time, then cooled in running water. Finally, they are labeled and packed in boxes ready for shipment.

Other Preservation Methods.

In this country, the one preserving method, other than canning, is drying or powdering. The oyster powder, put up in vials for family use, makes, with the addition of hot water and the usual seasoning, a broth, or, with the further addition of milk, a stew of great excellence. The business has not been an exceedingly large one. Although this process could hardly be expected to compete with the fresh oyster trade, it might compete with canning.

In Mexico a salting or "curing" method is employed for oyster preservation. According to the description,[10] this process consists of "toasting" the oysters for easy opening, and in thoroughly salting the "meats" in a tin container. Doubtless other simple preservation methods are employed in various parts of the world.

By-Products.

The useful by-products of the oyster trade are the various shell products. Untreated shells are used to a certain extent for road material. They possess the advantage that they crumble under traffic and thereafter bind together fairly well. However, they do not make a first class road material and doubtless will be used less and less for this purpose. The principal shell products are those which depend for their value mainly on the calcium carbonate content of the shell. These are crushed shells or "grit," used as poultry food to furnish calcium for egg shells, and "burnt" shells or lime used for fertilizer. Shells to be crushed are first dried in a heated rotary drier, then crushed and screened into various sizes or grades. Shells are "burned" by heating in vertical kilns into which they are taken by conveyor and chute. The "burned" shells are allowed to air-slake before being used to correct soil acidity.

[10] Radcliffe, L., *Bureau Fisheries, Doc. 931* (1922), 11.

Chemical Composition of Oysters.

Work on the composition of oysters has been concerned mainly with the percentage of water, salt, ash, and total solids. Years ago Atwater, and more recently Hindman and Goodrich, made determinations of protein, fat and carbohydrate content. Determinations have been made for particular constituents such as copper, iron, zinc, manganese and arsenic. As with most fresh foods, the water content of oysters is high. The protein content is relatively low, and the fat content still lower. Glycogen, however, has been found by Mitchell in relatively large quantities in "fat" oysters, and seems to be an index of condition or "fatness."

Protein and glycogen together give a considerable food value to oysters. Ease of assimilation is supposed to be another good point. Presumably, however, far and away the strongest dietary argument for oysters, in the absence of evil effects if they are prime and eaten in moderation, is their great deliciousness.

From the various analyses the following data are selected:

TABLE 64

AVERAGE OF 14 SAMPLES OF UNSHUCKED OYSTERS[11]

Average Weight	In Whole Sample		In Flesh		In Liquids	
Grams	Flesh, Per Cent	Liquids, Per Cent	Water, Per Cent	Solids, Per Cent	Water, Per Cent	Dry Substance, Per Cent
113.8	9.47	7.42	81.43	18.57	95.69	4.71

TABLE 65

SHELL CONTENTS[11]

	Moisture, Per Cent	Dry Matter, Per Cent	Protein, Per Cent	Fats, Per Cent	Carbohydrates, Per Cent	Mineral Matters, Per Cent
Best	80.8	19.2	8.2	1.7	7.3	1.6
Average	87.3	12.7	5.7	0.9	3.2	2.9

TABLE 66

COMPOSITION OF THE FLESH OF EASTERN AND WESTERN OYSTERS[12]

	Protein Per cent	Fat Per cent	Carbohydrates Per cent	Ash Per cent
Atlantic Coast oysters	7.4	1.62	3.2	2.12
Western natives	7.58	1.64	3.4	2.07

In his analyses for glycogen Mitchell[13] found that this varied from 3.05% to 22.46% of ash-free solids.

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[11] Atwater, W. O., *U. S. Fish Comm., Bull. 4* (1884), 204.

[12] Hindman and Goodrich. *American Food Journal,* No. 12, 1917, 611.

[13] Mitchell, P. H., *Bureau Fisheries, Doc.* 851 (1917), 480.

Copper, iron and zinc are present in appreciable quantities. Manganese has been found. The following figures were obtained by Skinner and Sale[14] with poor oysters from York River, Va., and are based on the weight of drained oyster meats:

Copper,	70 parts per million.
Iron,	160 parts per million.
Zinc,	60 parts per million.

Besides the analyses of the fleshy parts of the oysters there have been several of the shells. Among these, because of its completeness, the following is selected:

TABLE 67

ANALYSIS OF OYSTER SHELLS MADE BY THE U. S. BUREAU OF CHEMISTRY FOR THE U. S. BUREAU OF FISHERIES

(Received September 8, 1922)

Constituent	Oyster Shells		
	A Per Cent	B Per Cent	Average Per Cent
Aluminum	.045	.043	.044
Calcium	38.78	38.81	38.80
Copper	....	.0025	....
Iron (Fe)	.11	.09	.10
Magnesium	.183	.189	.186
Manganese	.009	.009	.009
Phosphoric Acid (P_2O_5)	.075	.073	.074
Silica	.57	.58	.575
Zinc	....	.0009	....
Organic matter (loss above 110° C.)	1.41	1.51	1.46
Water (loss to 110° C.)	.27	.28	.28
Chlorine	.0034	.0035	.0035
Carbon Dioxide	....	....	41.96
Fluorine	....	Absent	....
Nitrogen	.196	.196	.196
Arsenic	....	Absent	....

Duplicate analyses were made as indicated by "A" and "B" in above table.

The iron determinations were made on later samples sent over by request, as indicated in letter from Bureau of Fisheries to Bureau of Chemistry, dated Dec. 16, 1921.

Changes During Canning and Storage.

Shucked oysters keep but a moderate length of time even if held at a low temperature. Care in handling and prompt chilling, to just above the freezing point, help considerably. Bacterial attacks may be followed by that of "pink yeast," and presumably other organisms. Little is known concerning the chemistry of spoilage. Oysters in bad condition sometimes are canned. If deterioration goes on rapidly after canning, considerable gas pressure may be developed with consequent bulging of the ends of the cans.

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[14] Skinner, W. W. and Sale, J. W., Chemical investigations of pulp mill effluents, West Point, Virginia, and of the York River from West Point, Virginia to Chesapeake Bay. Manuscript Report from U. S. Bureau of Chemistry.

Danger of Infection from Eating Raw Oysters.

The wonderfully fine straining apparatus of oysters takes from the water bacteria, which may include the typhoid bacillus if present in the water. Where these are numerous, sufficient accumulations may occur in oysters to render the eating of them dangerous in a raw state. More and more this is coming to be understood and guarded against. In general, where oysters are still grown in badly polluted water, the law requires that, before being marketed, they be transplanted for a given length of time to natural waters of sufficient purity. A recently developed alternative is the placing of them in tanks, the water of which may be artificially sterilized by one of several chlorination methods. This is made possible by the fact that the oyster closes its shell when irritated by the chlorine, and so escapes harm, and when not closed draws in and forces out a great volume of water, and so gives itself a very thorough washing. Oysters go into a state comparable with hibernation when the water temperature drops to 45° F. In this condition it is held they may safely be taken from water of moderate contamination because accumulation in the shell no longer occurs.

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Chapter 28.

The Clam Industry of the United States.

The Commercial Importance of the Clam.

Although clams have been recognized as articles of food since antiquity, only in recent years have they been highly esteemed. In America, clams are eaten chiefly by the inhabitants of the states along the Atlantic seacoast. Recently clams have become popular as a food on the Pacific Coast and an important industry has been developed in that region. Small hard clams called little necks have become very popular in New England and are eaten both raw and steamed in the shell. Comparatively small quantities of clams are shipped from the Atlantic Coast to the inland cities.

Massachusetts possesses the most important clam fisheries of any state in the Union and produces over 3 million pounds of clams each year. The Maine clam industry ranks second, the annual production being in excess of 2 million pounds. Other states possessing important clam fisheries are Rhode Island, Connecticut, New York, North Carolina and Washington. New England produces chiefly soft clams. From New York southward, the hard clam is the only commercial clam of importance. The razor clam is the most important clam in Washington and Oregon. The annual product of canned clams exceeds in value the total quantity of clams marketed fresh. The latest available statistics of the clam industry of the United States are presented in Tables 68 and 70.

Species of Clams Commercially Utilized.

Two important species of clams are found on the Atlantic Coast of North America: *Mya arenaria,* the soft clam; and *Venus mercenaria,* the hard clam or quahaug. The large surf clam *Mactra solidissima* has a limited use as bait and is occasionally eaten by man but is of almost negligible present commercial importance.

On the Pacific Coast, a number of species are utilized. Of these the razor clam *Siliqua patula* is perhaps the most highly esteemed. It is used both fresh and canned. The Atlantic species *Mya arenaria* has become widely established and in some regions forms the basis of a considerable fishery. Other clams of importance commercially are *Tivela stultorum,* the "Pismo clam"; *Paphia staminea,* known as "little neck clam" or "rock cockle"; *Schizothærus nuttalli* variously known as "Washington clam," "great Washington clam," "great blue clam," and "gaper"; two species of *Saxidomus—Saxidomus nuttalli* and *Saxidomus giganteus,* which also are called "Washington clam" (not because of their distribu-

TABLE 68

SHOWING THE LOCATION* OF THE CLAM INDUSTRY OF THE UNITED STATES

	Year	Weight	Value	Species
Maine	1919	2,015,734 lbs.	$163,209	Soft
New Hampshire	1919	66,600	13,320	Soft
Massachusetts	1919	2,187,630	242,944	Soft
"	1919	875,944	283,767	Hard
"	1919	23,300	3,500	Razor
Rhode Island	1919	403,760	24,075	Soft
" "	1919	156,232	59,649	Hard
Connecticut	1919	229,150	32,070	Soft
"	1919	49,976	18,912	Hard
New York	1921	770,224	216,478	Hard
" "	1921	188,150	32,995	Soft
" "	1921	48,160	11,300	Skimmers or surf
New Jersey	1921	782,088	364,548	Hard
" "	1921	143,500	20,650	Soft
Delaware	1921	4,040	2,340	Hard
Maryland	1921	30,200	10,275	Hard
Virginia	1920	449,440	229,645	Hard
North Carolina	1918	197,576	46,598	Hard
South Carolina	1918	800	200	Hard
Georgia	1918	120	75	Hard
Florida	1918	163,272	14,936	Hard
California	1915	65,856	17,583	Hard
"	1915	67,160	18,107	Soft
Oregon	1915	22,460	3,041	Soft
"	1915	77,200	10,900	Razor
Washington	1915	175,444	12,191	Hard
"	1915	1,200	150	Soft
"	1915	372,750	56,446	Razor

*The clam fishery in Texas, Louisiana, Alabama and Mississippi is not of commercial importance.

tion) and sometimes "butter clam"; and *Macoma nasuta,* the "bent nose clam."

Life Histories of Most Important Species of Clams Utilized Commercially.

Mya arenaria commonly called soft clam, long clam, long neck, squirt clam, mananose, sandgaper and old maid is found from South Carolina to the Arctic Ocean. It is the principal species north of New York. About 1870, this clam was introduced into Pacific Coast waters and now it is widely distributed along the Pacific Coast.

The life history of this clam is very interesting. The male and female cells are extruded into the water where they unite, and form a swimming embryo which rotates spirally. When the little clam has grown to be about 0.003 inch in diameter an embryonic shell appears. The length of the swimming period varies somewhat with the temperature of the water, being, according to Shellford, from 3 to 6 days in length. Millions of these young swimming clams can be found over the clam flats during the reproductive season which lasts from the middle of June until September in waters along the Atlantic Coast south of Cape Cod. A muscular foot, a siphon, and gills appear during the later part of the swimming stage. The projecting pad covered with the swimming cilia called the velum gradually disappears and the small clam soon settles to the bottom. When it reaches the bottom a glandular fluid is secreted, which, on being ejected into the water, hardens into a minute thread called the byssus; the tiny clam attaches itself to shells, seaweeds or pebbles by means of this thread. It does not remain stationary at this stage, but often detaches the byssus and creeps about by means of its foot. When the shell has become about 0.01 inch in length, the young clam begins burrowing into the bottom. When completely buried it spins another byssus and again attaches itself. Occasionally newly buried clams discard the thread, and come to the surface, creep a short distance and then burrow into the bottom again. When the young clams become about a half inch long they burrow deeper into the bottom and are believed to remain buried through the rest of their lives. Clams grow from a length of one inch to about three inches in a single year.

Venus mercenaria is commonly called quahog or quahaug, hard clam, round clam, and in the smaller sizes cherry stone clam and little neck clam; this clam is common from Cape Cod to Texas. From New York southward, the quahaug is much more abundant than the soft clam and therefore it is simply called "the clam." Its life history has been studied by Belding [1] and has been found to be strikingly similar in the early stages to that of *Mya arenaria* which has been described above, but growth to commercial sizes is decidedly slower.

Siliqua patula is the most important native Pacific Coast clam and is found on nearly all the sandy beaches from Oregon to Alaska. They obtain their name "razor" from their shape, being rather long and narrow. When disturbed they burrow rapidly into the sand to a depth of 2 or 3 feet forming large elliptical holes in the sand.

Chemical Composition of Clams.

Numerous proximate analyses of clams have been published but to the author's knowledge, no comprehensive researches on the composition of clams have been carried out. The data concerning the composition of soft and hard clams were taken from Atwater's analyses as presented by Langworthy.

Buttenberg [2] gives the percentage of shell and muscle of a soft clam 13 cm. long and 8 cm. wide as follows:

Shell	45.9%
Siphon	9.1
"Herzteil"	12.5
Muscle	32.5
	100.0

---

[1] Mass. State Biologists Rept. Quahaug and Oyster Fisheries of Mass., 1912.

[2] *Nahr. Genussm., 22* (1911), 81-8. "Herzteil" evidently refers to the visceral mass.

TABLE 69

PROXIMATE COMPOSITION OF CLAMS[3]

	Refuse Shell, etc.	Moisture	Protein (N × 6.25)	Fat	Carbohydrates	Mineral Matter	Total Nutrients
Soft clams, in shell	41.9%	49.9%	5.0%	0.6%	1.1%	1.5%	8.2%
Soft clams, canned	....	84.5	9.0	1.3	2.9	2.3	15.5
Quahaugs, removed from shell	....	80.8	10.6	1.1	5.2	2.3	19.2
Quahaugs, in shell	67.5	28.0	2.1	0.1	1.4	0.9	4.5
Quahaugs, canned	....	82.9	10.5	0.8	3.0	2.8	17.1

Contamination by Pathogenic Organisms.

Clams are liable to bacterial contamination by the same organisms found in oysters growing in polluted saline waters. Oystermen are able to establish their beds far from shore where there is little danger from contamination by sewage from nearby cities and towns. Since the soft clam *Mya arenaria* and the razor clam, *Siliqua patula* are found chiefly on the shore between tide lines there is much more danger of contamination of these clams by polluted waters. Clams dug in the vicinity of large cities should always be cooked before being eaten. Steaming, baking and frying quickly kill pathogenic organisms such as *Bacillus typhosus* which may be present.

Clam Culture in New England.

Because of the great decline of the New England clam fisheries, much has been done to encourage clam farming. Numerous detailed reports concerning its feasibility have been published by the Fish and Game Commission of Massachusetts. The culture of both the hard and the soft clam is carried out in a limited way in New England. Small areas are found in nearly every harbor where small soft clams (seed clams) are found in enormous numbers at certain seasons of the year. These heavy sets run as thick as 2,000 per square foot of surface. The seed clams are usually obtained from the areas of heavy set by washing the small clams out of the sand or mud by means of a cradle shaped sieve. The small clams are "planted" on suitable tidal flats and grow to marketable size within a year or two.

The collection of the seed clams or spat is much more difficult in the case of the quahaug clam; inasmuch as the small hard clams are never found in vast quantities. Although as many as 75 young quahaugs per square foot may be sometimes caught in box spat collectors, this method of catching spat has not proved profitable. Since the young quahaugs (little necks) bring high prices, methods of quahaug farming for the production of little neck clams have been suggested. By this system the larger older quahaugs are kept as seeders, the "little necks" alone being marketed.

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[3] Langworthy, C. F., U. S. Dept. Agr, *Farmers' Bull. 85,* revised (1907).

Razor Clam Cultivation in Japan.

During recent years the Japanese have cultivated a clam called "agemaki" (*Solecurtus constrictus*) which is similar in appearance to the razor clam. The young clams are collected when they are about two inches in length, being dug out of the mud on the tidal flats with spades. They are covered immediately to protect them from the sun and are scattered on the culture grounds, where they burrow into the mud. They are left for about three years; during which they grow to be about four inches in length. This industry is growing rapidly. The chief centers are in the following prefectures: Kanagawa, Chiba, Miyagi and Hokkaido.

The Atlantic Coast Industry.

Soft Clam.

The early New England settlers learned soon after their arrival of the valuable beds of soft shell clams that existed on many of the tidal flats along the Atlantic Coast. In times of want, the early colonists depended upon this natural food supply which was so readily obtainable. There was some local trade in clams but as there were no inland markets the demand was limited. Early in the nineteenth century, the fishermen began to use large quantities of clams as bait. About the year 1875, the value of the clam as food began to be recognized more generally throughout the eastern states. A period of overfishing followed which depleted many of the most valuable clam flats. Now, much attention is being given to the restocking of the exhausted beds.

Two methods of digging of soft clams are commonly employed; one of these methods called "wet" digging is carried on when water is over the clam flats; whereas "dry" digging takes place when the beds are left exposed by the tide. Dry digging is by far the more common practice. Submerged clams are dug with an instrument that is known locally as a "sea horse" which is an enlarged clam hoe, with prongs 12 to 14 inches long and a strong wooden handle about four feet in length. This handle has a belt attachment which is buckled around the clammer. The sea horse is worked deep into the loose sand and is dragged by one man, who wades in the shallow water over the submerged flats, while his partner follows gathering the clams upturned by the sea horse. Forks or hoes are occasionally used for this wet digging.

The rake or digger used in dry digging much resembles a potato digger but varies with the soil of the clam flat. Where the soil is loose and sandy or gravelly, diggers with broad prongs are used, but for hard mud flats, they should have thin, sharp prongs. The angle which the handle makes with the prongs of the hoe is a matter of choice with the individual clam diggers, varying from a right angle to an angle of 60 degrees. In a few districts spading forks are used by the clammers. The baskets used for holding the clams gathered by the diggers are usually made of uniformly spaced lath so as to permit draining and easy washing. Inasmuch as the dry digging of clams is possible only between tides, the work lasts only a few hours at a time. The quantity of clams gathered varies widely with different individuals and with the abundance of the clams and usually varies from 1 to 4 bushels.

Clams are either marketed in the shell or "shucked out." In either case the clams must be carefully washed. Small clams suitable for steaming are ordinarily shipped to market in the shell as are also the fine appearing sand clams. The unprepossessing mud clams and the very large clams are usually shucked by removing the shell and the external covering of the siphon or neck. A bushel of clams produces about 7 quarts of shucked clams. Shucked clams readily absorb a considerable quantity of fresh water; after soaking for about 6 hours they increase in volume about a third. Consequently, the shucked clams are soaked before being marketed. In addition to increasing their bulk, the soaking process plumps the clam meats.

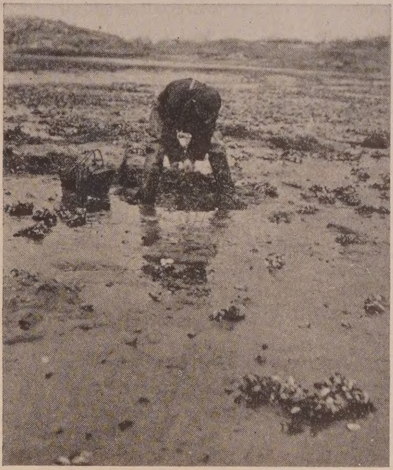


FIG. 193.—Digging soft clams on the flats of the Squam River at Gloucester, Massachusetts.

The clams shipped in the shell are usually packed in second hand flour and sugar barrels, while shucked clams are usually shipped in kegs or butter tubs. The chief markets for soft clams are Boston, New York, Baltimore and Philadelphia.

Hard Clam Fishery.

Inasmuch as the quahaug clam was considered inferior in quality to the soft clam, little attention was given to it commercially until about the beginning of the nineteenth century. But the hard clam fishery did not become of great importance until the beginning of the twentieth century when the popular demand for "little necks" or the small quahaug clams spurred production to the limit of the natural clam resources.

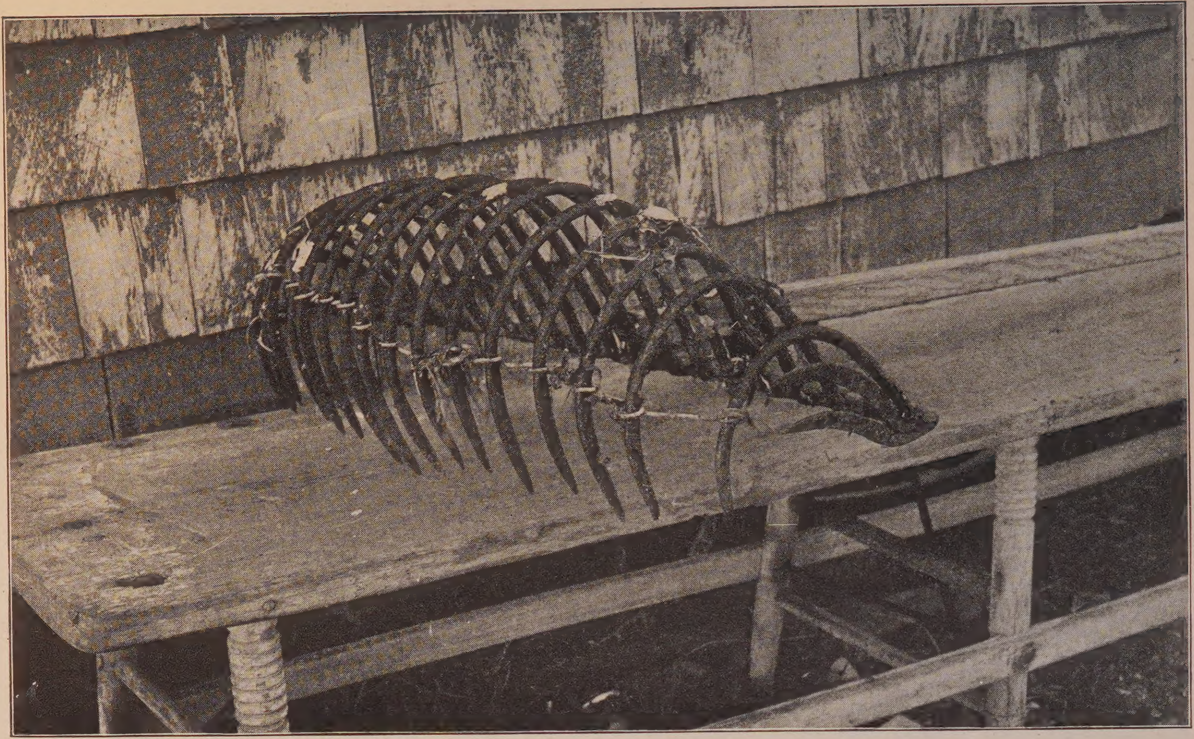
There are two types of quahaug fisheries on the Atlantic Coast. The deep water fishery is vastly more productive than the shallow water industry. Belding reports that in 1907, the deep water hard clam fishery of Massachusetts yielded 118,500 bushels whereas the shallow water fishery produced only 23,227 bushels of clams. Both power and sail boats are used in deep water quahauging.

The quahaug fishery of the Atlantic Coast is located chiefly in Massachusetts, Rhode Island, New York, North Carolina and Florida. Quahaugs occur, however, all along the Atlantic Coast from Massachusetts to Florida and along the coast in the Gulf of Mexico. The chief centers of the industry in Massachusetts are Chatham, Eastham, Edgartown, Fairhaven, Orleans, Wareham and Wellfleet. The culture of quahaugs is carried on chiefly in Orleans, Eastham, and Wellfleet. The quahaug fishery is an important industry in Long Island Sound and in the various Long Island bays, notably Great South Bay. The North Carolina clam industry is centered in Brunswick, Carteret, New Hanover and Pender counties.

There are still great beds of these clams in the south that have never been disturbed. Many beds are found along the shores in the Gulf States but they are dug commercially only on the west coast of Florida.

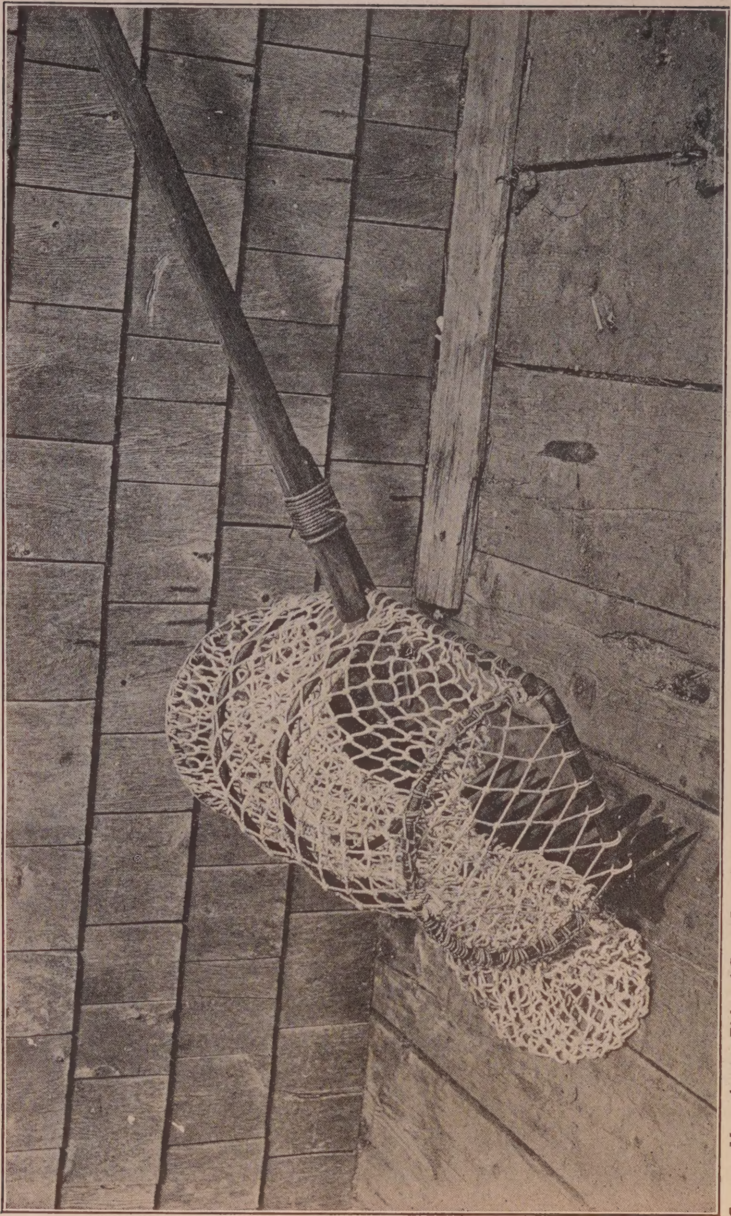
The Indians obtained their hard clams by the primitive method of "treading"; the "treader" finds the clams by wading about barefooted in the shallow water feeling in the soft mud for the quahaugs with his toes and then picking them up by hand. The early settlers soon learned more rapid ways of gathering the shellfish. Some quahaugs are obtained by raking them out of the mud on the exposed tidal flats by means of short rakes or hoes. Because of the scarcity of hard clams between the tide lines, this method is now chiefly employed by fishermen seeking clams for their own use. Some clams are also gathered by means of oyster tongs (see page 519) or clam tongs of similar design. This method is applicable only in shallow water as the tongs are seldom longer than 16 feet. Tonging is carried on in small coves and inlets where the water is usually very quiet. By far the most important way of taking quahaugs is by means of rakes. Belding[1] has described the various types of rakes used in the quahaug fishery of Massachusetts in the following manner:

> *The Digger.*—In some localities, chiefly in Buzzard's Bay, the ordinary potato digger or rake, having four or five, long thin prongs, is used. Usually it has a back of wire netting which holds the quahaugs when caught by the prongs. As the digger has a short handle of 5 feet, it can be used only in shallow water, where the quahauger, wading in the water, turns out the quahaugs with this narrow rake. This method yields but a scanty return, and is more often used for home consumption than for market.
>
> *The Garden Rake.*—The ordinary garden rake, equipped with a basket back of wire netting, is in more general use in shallow water, either by wading or from a boat, as it has the advantage of being wider than the potato digger.
>
> *The Claw Rake.*—This type of rake varies in size, width and length of handle. It is used chiefly at Nantucket. The usual style has a handle 6 feet long, while



Courtesy Massachusetts Fish and Game Commission.

FIG. 194.—The claw quahaug rake.



Courtesy Massachusetts Fish and Game Commission.

FIG. 195.—A type of basket rake used for deep water quahauging on Cape Cod.

the iron part in the form of a claw or talon is 10 inches wide with prongs 1 inch apart. Heavier rakes with longer handles are sometimes used for deep water, but for shallow water the usual form is the short-claw rake.

The Basket Rake.—The greater part of the quahaug production is taken from deep water, with the basket rake. These rakes have handles running from 25 to 65 feet in length according to the depth of water over the beds. Where the water is of various depths, several detachable handles of various lengths are used. At the end of these long handles is a small crosspiece similar to the crosspiece of a lawn mower; this enables the quahauger to obtain a strong pull when raking. The handles are made of strong wood and are thin and flexible, not exceeding 1½ inches in diameter. . . . Three forms of basket rake are used in Massachusetts. These rakes vary greatly in form and size, and it is merely a matter of opinion which variety is the best, as all are made on the same general principle,—a curved, basket-shaped body, the bottom edge of which is set with thin steel teeth.

Quahauging by means of the basket rake has also been described by Belding:

When the quahaug grounds are reached, the boat is anchored at both bow and stern, one continuous rope connecting both anchors, which are from 500 to 600 feet apart, in such a way that the bow of the boat is always headed against the tide. A sufficient amount of slack is required for the proper handling of the boat, which can be moved along this anchor "road" as on a cable, and a large territory raked. The rake is lowered from the bow of the boat, the length of the handle being regulated by the depth of the water, and the teeth worked into the sandy or muddy bottom. The quahauger then takes firm hold of the crosspiece at the end of the handle, and works the rake back to the stern of the boat, where it is hauled in and the contents dumped on the culling board or picked out of the net. In hauling in the net the rake is turned so that the opening is on top, and the mud or sand is washed out before it is taken on board. The long pole passes across the boat and extends into the water on the opposite side when the rake is hauled in. This process is repeated until the immediate locality becomes unprofitable, when the boat is shifted along the cable. The usual time for quahauging is from half ebb to half flood tide, thus avoiding the extra labor of high water raking.

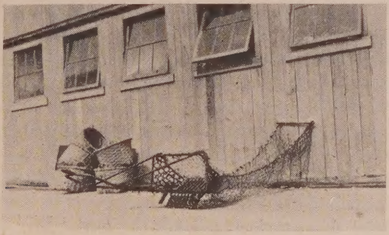


Photo by J. S. Gutsell.

Fig. 196.—Nantucket deep water clam dredge.

Besides the method described by Belding, dredging is sometimes used. Where clams are plentiful on private oyster grounds the ordinary oyster dredge may be used. For deep water beds such as occur near Nantucket a special narrow, long toothed, "deep water clam dredge" has been developed. (See Fig. 196.)

The hard clam fishery is essentially a summer fishery; the season in

Massachusetts lasts for seven months, usually starting the last of March and ending about the first of November.

The clams are washed soon after they are brought ashore and graded into various sizes; the most generally recognized grades (in Massachusetts) are the following: (1) "little necks"; (2) "sharps"; and "blunts." The "blunts" and "sharps" are the larger grades and are alike in every particular except the thickness of the edge of the shell. The blunts are thick-lipped and have a somewhat heavier shell than the "sharps," which are usually lighter in color and have sharp edges. The following dimensions are illustrative of the size of the grades: "Little necks," small, 1.5 to 2.25 inches; large "little necks,"[4] 2.25 to 3 inches; medium "sharps" 3 to 3.75 inches; large "sharps" 3.75 inches up.

The quahaugs are shipped either in barrels or bags. Holes are cut in the bottom and sides of the barrels to allow circulation of air and to permit drainage of water; burlap is used instead of wooden heads in the barrels.

If the market for the hard clams is dull at the time of the catching of the clams, the clams are often bedded in sand on the tidal flats until the market improves. The fisherman has only to spread his catch on the surface and the quahaugs will burrow into the sand and continue their growth. Some fishermen spread their clams on floats which they lower into the water where the clams are kept alive until needed. The advantage of the use of floats is that the clams need not be dug a second time and may be easily and quickly obtained for market when desired.

The chief markets for New England quahaugs are Boston and New York. Quahaugs will live out of water very much longer than the soft clam. It may be safely shipped far inland even in summer. It is therefore better known in the markets of the Mississippi Valley than the soft clam. Some quahaugs are canned in Florida.

The Pacific Coast Clam Industry.

The chief commercial clam of the Pacific Coast is the so-called razor clam, *Siliqua patula.* The most important clam fisheries of the Pacific Coast are located in Clatsop County, Oregon; Grays Harbor and Pacific counties, Washington; and near Cordova, Alaska. This clam is chiefly found in the sand between the tide lines. The clammers chiefly use short-handle spades in digging them. The clams are most numerous near the low water mark; because of this, the best digging is during the spring tides when the greatest run-out occurs at low tide. Because of the danger of overfishing for these clams, a closed season has been inaugurated in Washington from June 1 to September 1.

Preservation of Clams.

Canning.

The only important process of preservation of clams is canning. Small quantities of clams are preserved by other methods including pickling, salting, drying, and smoking; but the amount of clams preserved in America by these methods is insignificant. However, the Japanese dry considerable quantities of razor clams.

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[4] Corresponds approximately with the size known on Long Island and in the New York market as "cherrystones."

In the year 1921, the value of the clams canned in the United States was $1,166,507. More clams were packed in Washington than in any other state in the Union. Other important clam canning states are Oregon, Maine, Massachusetts, and Florida. The quantity and value of clams and clam products canned in the United States by states in 1922 is given in Table 70.

Razor Clam Canning.—Statistics given in the table indicate that more razor clams are canned in the United States than any other species; the greater proportion of these are packed in the state of Washington; some are also packed in Oregon and Alaska.

Much labor-saving machinery is employed in the more modern razor clam factories. Several of the up-to-date plants employ automatic shucking machinery. The automatic shucker consists of a long rectangular box containing a rack which is operated as a rocker. The motion of the rocker carries the clams toward the opposite end of the trough and through hot water which causes the clams to gape. The motion of the rack shakes the meats out. When the meats and shells reach the opposite end, jets of cold water are played upon the meats to cool them rapidly in order to prevent them from becoming tough. The clam meats are picked off the frame and placed in large pans while the shells pass on and are dumped outdoors.

The meats are then dressed and cleaned. This is accomplished by splitting them on one side with scissors so that they are opened wide. The dark mass near the end of the siphon which contains much sand and dirt is clipped off. The cut meats are then washed in a special washing machine which usually consists of a cylindrical perforated drum which revolves first half a turn in one direction and then half a turn in the opposite direction. Next the siphon and side-walls are cut away from the washed meats and discarded. The stomach is then slit open and cleaned out. The cleaned, dressed meats are minced in a meat grinder. The ground meats are placed in the hopper of an automatic filling machine which feeds the desired quantity of clam meat into the cans which pass under it on an endless belt. Some of the juice of the clams which runs out during the dressing process is added to the filled cans. The tops of the cans are put in place and the cans of clams are exhausted at a temperature of about 210° F. for about 8 minutes. The tops are then sealed on to the cans, and the cans are processed at a temperature of about 220° F. 1 pound cans are processed for 90 minutes, and half pound cans are heated for 70 minutes. After processing, the cans are quickly cooled with streams of cold water to prevent the clam meat from becoming tough.

Clam Nectar.—During the grinding of the meats of the razor and other clams a considerable quantity of liquid is expressed. Although some liquor is added to each can of clams, a considerable surplus of this liquor remains. This is canned separately and sold under the name of clam nectar. The hot liquor is placed in one pound cans which are then sealed and sterilized. If the liquor is cold when it is put into the cans, they are exhausted

TABLE 70

Quantity and Value of Clams and Clam Products Canned in the United States During 1922

Hard Clams	Florida and Washington		Soft Clams	Maine, Massachusetts, and Rhode Island	
	Cases	Value		Cases	Value
Whole:			Whole:		
No. 1 cans (4 dozen)	15,018	$104,633	5 and 5½ ounce cans (4 dozen)	33,589	$157,809
No. 1 cans (2 dozen)	291	989	6 and 8 ounce cans (2 dozen)	6,155	22,916
No. 2 cans (2 dozen)	11,423	61,664	8 and 10 ounce cans (4 dozen)	14,099	84,015
No. 10 cans (½ dozen)	2,048	12,775	8½ and 10 ounce cans (2 dozen)	4,110	19,547
Minced:			1-pound cans (4 dozen)	4,212	25,000
½-pound flat cans (4 dozen)	358	1,792	2-pound cans (2 dozen)	3,743	18,000
No. 1 cans (4 dozen)	2,355	14,219	Bouillon, chowder, and broth:		
No. 2 cans (2 dozen)	883	4,415	8, 10, and 16 ounce cans (4 dozen)	14,334	74,320
No. 10 cans (½ dozen)	87	783	32-ounce cans (2 dozen)	15,267	81,760
Bouillon, chowder, and juice:			1-gallon cans (½ dozen)	1,126	6,000
No. 1 cans (4 dozen)	9,015	42,078	No. 1 cans (2 dozen)	20,000	49,000
No. 2 cans (2 dozen)	2,391	7,699			
No. 3 cans (2 dozen)	2,854	15,902			
No. 10 cans (½ dozen)	650	4,168			
1½ and 3 ounce bottles	1,102	2,371			
7 and 14 ounce bottles (2 dozen)	3,874	24,554			
Total	52,349	$298,042	Total	116,635	$538,367

Razor Clams	Washington		Oregon		Alaska		Total	
	Cases	Value	Cases	Value	Cases	Value	Cases	Value
Whole:								
No. 1 (4 dozen)	9,134	$78,185	500	$5,500	......	....	9,634	$83,685
No. 2 (2 dozen)	1,394	9,061	300	1,950	......	....	1,694	11,011
No. 10 (½ dozen)	138	966	.....	......	......	....	138	966
1-pound (4 dozen)	......	....	.....	......	1,434	$11,604	1,434	11,604
Minced:								
½-pound flat (4 dozen) .	51,099	291,422	1,907	11,349	18,078	74,520	71,084	377,291
No. 1 (4 dozen)	33,677	238,622	3,971	29,576	......	....	37,648	268,198
No. 2 (2 dozen)	3,209	19,027	909	5,699	......	....	4,118	24,726
10-ounce (4 dozen)	......	....	.....	......	11,732	89,634	11,732	89,634
1-pound (4 dozen)	......	....	.....	......	1,046	9,249	1,046	9,249
Juice:								
No. 2 (2 dozen)	1,076	3,228	.....	......	......	....	1,076	3,228
No. 10 (½ dozen)	52	364	.....	......	......	....	52	364
Total	99,779	$640,875	7,587	$54,074	32,290	$185,007	139,656	$879,956

before sealing in the same manner as in the canning of razor clams. The one pound cans of nectar are cooked for 1 hour in the autoclave at a temperature of 240° F.

Clam liquor is also obtained from clams of the genus *Donax,* too small for utilization in any other way.

Clam Chowder.—Clam chowder for canning is usually prepared from the hard or quahaug clam inasmuch as this clam possesses a pronounced clam flavor.

Cobb [5] gives the following directions for the canning of clam chowder:

> In preparing the chowder, to 2,500 quahaug meats are added the following ingredients: 25 pounds bacon, 25 pounds potatoes, 7 pounds onions, 25 pounds tomatoes, ¼ pound finely chopped parsley, ⅛ pound thyme, 1 ounce sweet marjoram, 1 pound salt, ½ pound ground white pepper and 15 gallons of water.
>
> The clams should be washed in cold water, drained and chopped. Cut the potatoes and bacon in dice, and place the water, clams, bacon, onions, potatoes and tomatoes, in kettle, bring to a boil and cook 10 minutes; then add other ingredients; stir thoroughly and place in cans. The cans are then topped and processed, No. 3 cans for 80 minutes at 250° F.; for quarts 50 minutes at 250° F.
>
> . . . .
>
> Clam chowder is usually packed in No. 3 cans, though it is also put up in No. 1, No. 2 and No. 10 cans.
>
> A condensed clam chowder is prepared in the same way as plain clam chowder. In preparing this only half the quantity of water is used. After all the ingredients are added and mixed, and the steam turned off, the liquid is drawn from the bottom of the kettle, the cans filled with the solid materials and covered with the liquid. They are then capped, tipped and processed, No. 1 cans 40 minutes at 250° F. When preparing this for the table additional milk or water can be added in the quantity most desirable.

Clam Extract.—Clam extract finds extensive use as a food for convalescents and invalids. It is usually prepared by placing fresh clams in the shell on racks or gratings in an autoclave. The clams are steamed for about 20 minutes; the heat cooks the clams and causes much of the juice which they contain to run out. The liquor is collected in pans under the racks. This liquor is filtered and concentrated by boiling. The concentrated extract is put into cans which are topped, sealed and sterilized by processing in an autoclave at 240° F. One pound cans are heated for an hour, whereas half pound cans are usually heated for 50 minutes at this temperature.

Various other methods of preparing clam extract are occasionally used.

The Smoking, Salting and Drying of Clams.

Large quantities of clams used for fish bait by the New England fishermen were formerly shucked, that is removed from the shell, and salted in barrels. The gradual decline of the hand line fishery effected a similar decline in the clam bait industry; and at present only a few barrels of salted clams are prepared annually for use as bait.

The earliest means of preserving clams employed by the savages were those of smoking and drying. The North American Indians strung clams on sticks or cords and dried and smoked them over their camp fires. And today, the Japanese and Chinese dry large quantities of clams and other shellfish. The Japanese dry a clam, *Solecurtus constrictus,* resembling in appearance our razor clam.

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[5] Canning of Fishery Products, Seattle, 1919.

By-Products.

Shells are the only by-products of the clam industry. Inasmuch as the clam shell possesses little value, little use is made of them except as oyster cultch and occasionally as material for the construction of roads and as poultry grit.

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Chapter 29.

The American Shrimp Industry.*

By ARTHUR ORR.°

Three marine species of shrimp are taken for commercial purposes. Of these the most important and abundant form is *Penæus setiferus,* which occurs throughout the range of the fishery from Beaufort, N. C., to Corpus Christi, Texas. The closely related species *P. brasiliensis* is much less abundant and may be distinguished from the other by the character of the groove along each side of the rostrum which extends nearly to the posterior margin of the carapace, while in *P. setiferus* this groove extends less than halfway back. As the fishermen do not recognize these differences, an estimate of the relative importance of *P. brasiliensis* is difficult. The third species, *Xiphopeneus kroyeri,* commonly known to the fishermen as "sea-bobs" or "seven-beards," is considerably smaller, differs in color and general appearance, and has a rostrum as long as or longer than the carapace instead of shorter, as in the species of *Penæus.* It is taken commercially only on the Louisiana coast, where it is used solely for drying when the larger species are unobtainable.

Shrimp are migratory in habit. They make their appearance along the coast at regular seasons, usually in the spring and in the fall. They are taken by the fishermen over a period of several weeks or months, the time varying according to the region, and at the close of the season they disappear, the fishermen knowing not whence they came nor whither they went. Even during the fishing season, the shrimp are given to sudden movements. In certain regions, a heavy northeast or east wind will cause their complete disappearance. Some fishermen think they move out to deeper waters, while others maintain that they burrow in the mud, supporting their theory by the fact that, after the wind calms down, they frequently return and take shrimp at the identical spot on which they were being caught before the heavy east wind caused them to disappear. Where the shrimp go between seasons is a matter of conjecture. Many theories are advanced by the fishermen, but none of them can be said to go beyond the realm of mere speculation.

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* The bulk of the matter contained in this chapter is based upon observations made by the writer in 1917 while making a study of the shrimp fishing and canning industries for the United States Bureau of Fisheries. Although it is probable that some changes have occurred since that date in the methods employed in these industries, it is believed that such changes would be found to be unimportant in character and that the methods herein described are, in the main, still followed.

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The Fishery.

By far the greater bulk of shrimp is taken in haul seines by the fishermen of Mississippi and Louisiana. The Mississippi fishery is concentrated at about three ports, the principal one being Biloxi, where a large number of canning factories are located. The Louisiana canneries are nearly all in or near New Orleans, but the fishing grounds are more or less scattered along the shores of Barataria and Timbalier Bays. Adjacent to many of the fishing camps are large drying platforms, where a large portion of the catch is preserved by sun-drying.

The Mississippi fishermen confine their operations in the spring generally to the waters of the Mississippi Sound. In the fall of the year, however, they visit the Louisiana marshes, often going as far as 80 miles from port and remaining as long as a week or ten days, or until they have taken a cargo of shrimp. The fishing fleet consists of two-masted schooners 35 to 50 feet in length, 14 to 20 feet in beam and ranging in net tonnage from 5 to 22 tons. The schooners carry crews of 6 men and are equipped with a gas boat 25 to 30 feet long of from 5 to 10 horsepower and two skiffs, one about 20 feet in length in which the seine is carried and from which it is laid around the school of shrimp preparatory to the haul, and the other somewhat shorter, which is used for landing the shrimp from the seine.

The seines average about 200 fathoms in length and 14 feet in depth, consisting of a bag 25 to 40 feet long and two long wings of equal length. As soon as the fishing grounds are reached, five of the fishermen put off from the ship in the power boat, carrying the two skiffs in tow, and patrol up and down the fishing grounds at the discretion of the captain, who constantly throws the cast net, sounding for shrimp. The schooner meanwhile, follows up the power boat as closely as the state of wind will permit. As soon as a school of shrimp is located, the motor boat is anchored and the crew takes to the seine skiff. If the water is not too deep, 2 men jump overboard at the point where it is desired to begin laying the seine. If the water is too deep, the end of the seine is attached to a long stake driven into the mud and the men remain in the seine boat. Two men row the boat, while a third pays out the seine. In case the water is too deep for jumping overboard, the "horseshoe patent" is lowered over the side of the boat by means of a davit and line, the lead-lines being properly inserted under the rollers before lowering it into the water. Two anchors are thrown out on the opposite side of the boat, from bow and stern, after which the haul is ready to be made. The lead-lines, passing under the rollers of the "patent," are brought up side by side and hauled into the center of the boat, the cork lines passing to either end of the skiff.

Where practicable, the haul is always made to the beach, but where the beach is as much as 100 to 150 yards away, the round haul is employed. In hauling overboard, one man is stationed at each lead-line and two at each cork line. The lead-line men stand side by side inside the webbing, each one facing his own cork line, with the foot nearest the bag of the seine over the lead-line, drawing the lead-line up on the inside of the foot.

When the seine is all hauled in, the shrimp having been forced into the bag of the seine, the bag is closed up by throwing the lead-line over the cork line and the smaller skiff is brought alongside, riding directly across the bag. The cork line is hooked over the oar pins of the boat, the lead-line being held up by four of the crew remaining in the water. These men now begin what is called "making up the bag," turning it inside out until all the slack has been "made up," after which the two men in the boat dip out the shrimp with a dip net.

The two men in the skiff now row it alongside the schooner and shovel the shrimp aboard, the schooner having very low decks, while the remaining four men "boat the seine," replacing it in the seine skiff ready for another haul. The shrimp are then packed with chopped ice in the hold of the schooner.

In the Louisiana fishery, fishing camps are established on the shores of Barataria and Timbalier Bays, from which the fishing grounds are visited in gas boats, the fishermen returning to camp each evening. Power boats from New Orleans visit the fishing camps at frequent intervals and transport the shrimp to the factories, following the bayous and canals, with which the intervening territory is netted, and which constitute the principal highways for travel and transportation in that section of the state.

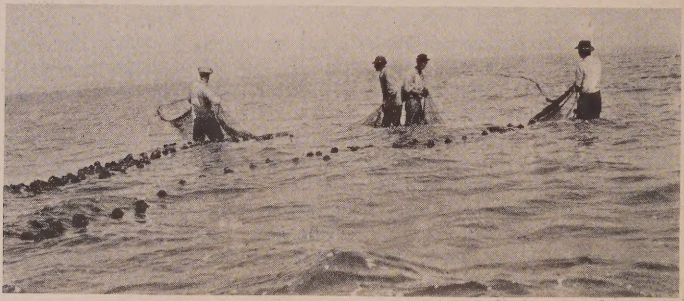

FIG. 197.—Hauling shrimp seine, Biloxi, Mississippi.

The haul seines used in this region differ materially from those used in the Mississippi fishery. The average seine is about 300 fathoms in length. It consists of two wings of equal size, on either side of a bag about 20 feet in length. The seine is about 12 feet deep at the bag, and each wing gradually tapers to about 6 feet in depth at the end. The seine is usually about 165 meshes deep at the bag, and every stretch (about 9 fathoms) of webbing is cut 5 meshes narrower, thus gradually reducing the depth of the seine to about 85 meshes at the outer ends.

Owing to the greater length of the seines and the heavier twine of which they are made, the Louisiana fishing crews are much larger than those in Mississippi, averaging from 12 to 16 men each, as compared with 6 men in the latter state.

When the fishermen approach the fishing grounds, the throwing of the cast net is begun. Two men usually stand on the stern, one on either side of the boat, each one constantly casting the net and hauling it in. Although shrimp are sometimes caught on sandy bottoms, they seem to prefer mud bottoms, and these are the spots usually sought by the fishermen. The shore is usually rather closely followed because, whenever possible, the seine is always hauled to the beach.

As soon as the cast nets indicate the presence of a school of shrimp, the boat approaches the shore to a point where the water is about waist deep, when, in the case of a crew of 12 men, 5 men jump overboard and hold the end of the seine. These men are said to be "on picket." The boat now steers a semi-circular course out to sea, two men standing on the stern and paying out the seine, one at the lead-line and the other at the cork line. As soon as the bag is thrown out, the boat again steers its course shoreward, so that when the seine is all paid out, the two ends are close inshore about 300 feet apart, and the seine lies out to sea in a half-moon shape. The boat is anchored and all hands "abandon the ship." The two ends of the seine are first closed up to within about 100 feet of each other, and about three-fourths of the seine is hauled in; after which the seine is entirely closed up and the hauling continues until the bag is reached. During the hauling process, one man at each end stands with his foot over the lead-line, so that throughout the entire haul the lead-line may closely follow the bottom of the bay and prevent the escape of the shrimp. Each lead-line man stands facing the webbing of the seine, with the toe of one foot placed over the lead-line. The haulers stand within about 3 feet of the lead-line men. As the seine is hauled in, the slack is passed into the water behind the fishermen. Toward the end of the hauling-in process, the two lead-line men stand very close together, sometimes almost back to back, to prevent the escape of the shrimp.

When the seine is all hauled in and the shrimp crowded into the bag, the bag is closed up by throwing the lead-line over the cork line, and, while the rest of the crew hold the bag shut, one of the fishermen brings the boat alongside, steering it directly across the bag, but with the mouth of the bag between the boat and the shore. Another fisherman now gets into the boat and two anchors are thrown out, one from the bow and the other from the stern. The cork line of the bag is hooked over the oar pins of the boat. The ten men remaining in the water hold the mouth of the bag up at the lead-line and begin what is called "skinning in the knitting," or turning the bag inside out, until all the slack is "skinned in," when the two men in the boat dip the shrimp out of the bag with dip nets.

To reload the seine into the boat, four men station themselves in the stern, two standing on the deck on either side and two standing in the hold. Two men remain in the water and pass the seine into the boat, beginning at the outer end of one of the wings. Meanwhile, the balance of the crew is busily engaged in cleaning the catch, removing crabs, stingarees, and fish of various kinds. Frequently, edible fish are caught in the seine, and these are usually taken ashore and consumed by the fishermen.

The principal shrimp fishing ports of the Atlantic Coast are Fernandina, Florida, and Brunswick, Georgia. The shrimp are taken by means of otter trawls. Otter trawls have also recently become an important factor in the shrimp industry of Biloxi, Mississippi. Last season there were about 250 trawl boats in the Biloxi shrimp fishery. They range in sizes from fifteen to thirty-five feet and are equipped with gasoline engines.

On the Atlantic Coast, the trawls are from 22 to 75 feet across the mouth, the average being about 35 or 40 feet. The length is usually about one-fourth greater than the width. The tail end, or bag, is usually about 150 meshes around. The wings are from 3 to 5 feet in length. From the mouth to within 15 or 20 feet of the tail the net is made of No. 9 cotton twine, 2-inch mesh, stretched measure, and the bag is No. 12 or No. 15, 1½-inch mesh. The cork line and lead-line are made of ¾-inch to 1-inch tarred rope, the lead-line being from 3 to 9 feet longer than the cork line. Corks, 3 or 4-inch size, are hung from 5 to 8 feet apart. Standard molded leads weighing about 10 to the pound are used. From the wings to the corner pieces, they are spaced about 4 inches apart, the next three are about 12 inches apart, and the balance, to the center of the bag, are about 20 inches apart. In fishing, the tail is bunted up and a small buoy or float is attached by means of a ¾-inch line about 11 fathoms long. This enables the fisherman to recover the net in case it becomes torn loose from the tow lines. The mouth of the net is held open by otter boards constructed of one-inch planks of the desired length and in sufficient number to give the proper width.

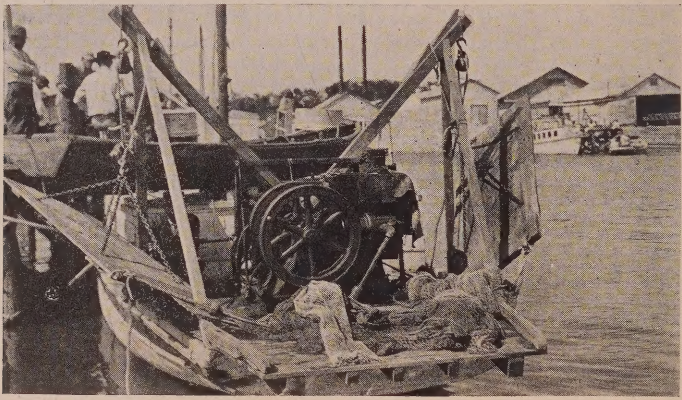

FIG. 198.—Power rig for hauling shrimp trawl, Biloxi, Mississippi.

Power boats of a wide range in size are employed in the otter trawl fishery, but as a rule the crew consists of two men. Many small boats, however, with crews of one man each, successfully engage in this fishery, while a few of the larger boats carry three men.

At the time of leaving port for the fishing grounds, the net is arranged on deck at the stern, the mouth of the bag being placed on deck first and the tail end on top. The otter boards are placed on either side of the deck, bridles up, the tow lines being coiled in the hold.

When the fishing grounds are reached, the engine is slowed down so that the boat does not travel more than from 2 to 4 miles per hour. The tail end of the net is first thrown overboard and the balance of the trawl quickly follows, the boards being the last to go. The amount of tow line let out in hauling the trawl varies, being usually about three times the depth of the water. The lines are attached to cleats on either side of the boat, the point of attachment varying in the different boats. However, best results seem to be obtained by attaching the lines as nearly amidships as possible, as it facilitates the steering of the boat during the trawling process.

After the net has been trawled for about 30 minutes, the engine is stopped and the net hauled in. The two men stand on the stern and each one hauls in on the tow lines until the otter boards are hauled aboard and the slack of the net hauled in. The tail end of the bag containing the catch is then worked around to the side of the boat and hauled aboard.

Composition.

The edible portion of fresh shrimp compares favorably in protein content with fresh fish. However, it has a very low percentage of fat and consequently has a low fuel value per pound. Recently various observers have found that many shrimp have a rather high fat-soluble vitamin content; this is of importance in considering their food value. The proximate composition of cooked, canned and dried shrimp is given in Table 71.

Marketing.

Iced Shrimp.—The bulk of the shrimp caught on the Atlantic Coast, particularly in Florida and Georgia, is shipped fresh, principally to northern markets. As a rule, the heads are removed, after which the shrimp are packed in ice in barrels, when they are ready for shipment. Certain markets, however, such as Charleston, South Carolina, and Havana, Cuba, demand the whole shrimp. Since the heads constitute from 40 to 45 per cent of the weight of the whole shrimp, the economy of heading prior to shipment is apparent.

TABLE 71

Analysis and Food Values of Shrimp

(Calculated on the fresh basis)

Constituents	Shrimp (edible portion)			
	Cooked	Canned (dry packed)	Canned (wet packed)	Dry
	Per Cent	Per Cent	Per Cent	Per Cent
Protein	27.6	25.5	20.0	71.4
Fat	1.0	0.8	0.5	5.0
Water	64.5	67.7	75.7	12.5
Salt	4.8	2.9	1.9	6.8
Comparative fuel value per pound (calories)	559	505	395	1,540

Extreme care is required in the handling of shrimp intended for shipping fresh, from the time they are removed from the fishermen's nets until they are placed aboard the train. Although many fishermen do not ice the shrimp at the time of capture, the chances of their reaching market in prime condition would be materially enhanced were they to do so. The shrimp should be headed and the bodies thoroughly washed and refrigerated promptly after being landed. This will prevent the accumulation of slime and of liquids from the stomachs of the shrimp, which are in the head portion.

In packing, a layer of ice is placed in the bottom of a barrel provided with drainage holes, and over this, a layer of chilled shrimp, then another layer of ice, and so on. A large cake of ice or "header" is placed on the top of the barrel. Another method is to place a long narrow cake of ice on end in the barrel and pack the shrimp around the cake. The header cake is placed on top and the barrel and its contents are covered with burlap.

Cooked Shrimp.—Limited quantities of shrimp are cooked in brine previous to shipment. In cooking, the whole or headless shrimp are placed in wire baskets and dipped into boiling 15 per cent brine for 15 to 20 minutes. The cooked shrimp are cooled in a chill room to 35° F. or less, and then shipped in a sealed package surrounded by ice. Occasionally, live steam is used for cooking shrimp. The shrimp are sprinkled evenly with salt and allowed to stand for a short time. They are then placed in a steam-tight box and steamed for a half hour. This process is advantageous as it obviates the necessity for making and handling brines, requires less salt, prevents soaking out of flavors and results in less loss in weight. Some shippers pack cooked shrimp in tight cans in light brine supposed to act as a preservative. The brines used contain about 8 per cent of salt. Heavier solutions tend to make the shrimp leathery and too salty; weaker ones produce softness and flabbiness in the stock and have no appreciable preservative effect.

Steamed shrimp, after being cooled, are packed in 1 to 5 gallon shipping tins that are lined with paper and provided with water-tight covers which are fastened tightly to the can. The sealed cans then are packed in burlap-covered barrels with drainage holes at the bottom. Such packages are re-iced by the express company when necessary, and, even in warm weather, can be transported in good condition.

Shrimp Preservation.

Canning.

Canned shrimp occupies an important place among canned marine products of the United States. According to statistics of the United States Bureau of Fisheries for the year 1922, shrimp ranked third in value among the canned fishery products of the United States and Alaska, being exceeded only by salmon and sardines, the latter including both herring and pilchards. There was packed in that year a total of 586,691 cases of shrimp with a value to the packer of $3,064,087. States contributing to the output were Louisiana, Mississippi, Alabama, Florida, Georgia, and North Carolina.

The writer has made extensive observations of the canning methods followed at the various packing centers. While there is a great diversity of procedure as pertaining to minor details, the fundamental operations were found to be practically identical. Rather than attempt to point out the differences in methods employed at the various plants, it is preferred to describe the operations found in use at a particular cannery, whose methods are believed to be typical of those followed in the industry as a whole.

If canning is not in progress at the time shrimp are landed, they are packed in chopped ice and held until enough shrimp are on hand to justify packing operations. The shrimp go from the fishing vessel or from the cold room directly to the picking tables, where the meat is separated from the heads and shells by women, boys, and girls, who are compensated according to the weight of shrimp headed. Each picker supplies himself with a bucket or can of alum water, into which the fingers are dipped from time to time. The celerity with which the pickers perform their work is quite remarkable. A shrimp is taken in the left hand, palm downward, being held by the tail or body portion, the legs pointing toward the body of the picker and the head pointing toward the picker's right hand. The head of the shrimp is first seized between the thumb and first two fingers of the right hand and broken or twisted off. The right thumb is now thrust between the right and left rows of legs, breaking open the shell, and, by running the thumb under the shell and around the body, peeling off a section of shell an inch to one and one-half inches in length. By squeezing the tail end of the shrimp between the fingers and thumb of the left hand, the meat is forced from the shell and allowed to drop into the meat bucket. In a day's time, the average picker will separate from 150 to 200 pounds of meat, a few of the more expert sometimes reaching 300 pounds.

After the meat is weighed, it is dumped into the first washing tank and the water turned on through a pipe extending over the top edge of the tank. After the tank has become about half full of water, a drain in the bottom of the wooden tank is opened and the water allowed to drain off as fast as it runs in. After a thorough washing in the first tank, the meat is transferred by means of a dip-net to the second tank and put through the same process as in the first. From the second washing tank, the meat is dipped into cane baskets and carried to the cooking tanks, which are heated by steam coils.

Steam is turned on in the coil and the water brought to a boil; after which the basket containing the shrimp meat is lowered into the tank. The wet packs are allowed to boil from 5 to 7 minutes, and the dry packs, from 10 to 12 minutes, the longer period of time being used when the shrimp are running large.

After the meat has been cooked, it is lifted from the tank in the cooking basket and dumped onto a light carrying tray, similar in construction to the cooling trays, on which it is carried to the cooling trays and dumped. The meat is now spread out to cool, and during the cooling process it is carefully gone over by girls, who pick out the legs and "whiskers," and remove the pieces of shell accidentally thrown into the meat buckets by the headers.

The length of time required for the meat to cool varies with the weather, and also depends on whether it is for wet packs or dry packs. For wet packs, the length of time required to go over the meat to remove the legs and shells is usually sufficient for the cooling process. The dry packs require a greater length of time to cool, due to the necessity of the meat's being thoroughly dry when it goes into the can. Otherwise, on being opened by the consumer, the meat would be more or less soggy, with perhaps a small quantity of liquor in the bottom of the can; and, while the meat will have kept as well as if it had been put into the can perfectly dry, it will not possess the attractive appearance which it otherwise would. Extreme difficulty is always experienced in damp weather in bringing the meat to the desired state of dryness for dry packing. No exact length of time required for the process can be given, as it varies with the condition of the atmosphere. The foreman judges the necessary length of time by feeling of the meat.

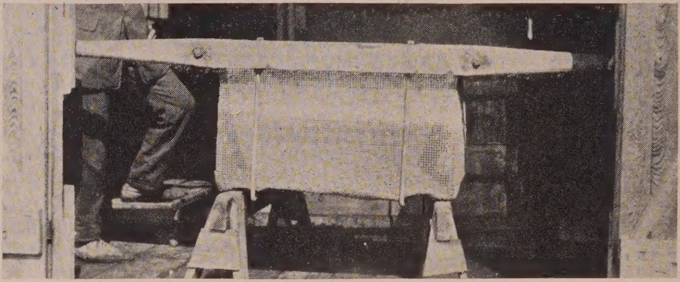

FIG. 199.—Cooking basket used in canning shrimp.

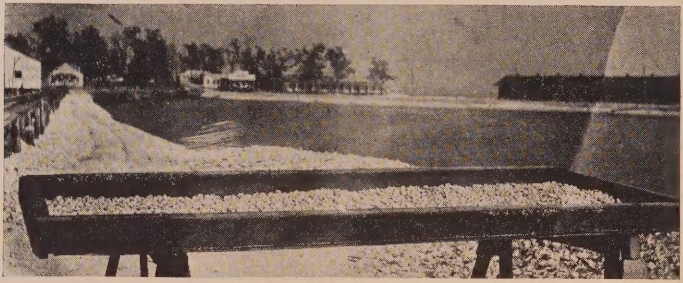

FIG. 200.—Cooling cooked shrimp on tray preparatory to packing in cans.

From the cooling trays, the meat is transferred to small carrying trays, on which it is carried to the weighing table. Two conveyor belts, one immediately above the other, about 4 or 5 inches in width, are located in the center of this table and extend its entire length. Six girls, standing in pairs, are stationed on each side of the table, facing each other. One girl fills the cans and the other girl weighs them. At the end of the weighing table farthest away from the sealing machines, cases of empty cans are piled, the cans having been lined with paper on the day previous. A girl feeds the empty cans onto the top conveyor, which carries them past the packers, who take them from the conveyor as they need them. The packers endeavor to put as nearly the required weight of meat as possible into each can. The weighers then set the cans, one at a time, on a small balance scale and add to the can or remove from it as much meat as may be necessary to make the scale balance. The can is then removed from the scale and placed on the lower conveyor belt.

The belt conveying the cans of meat runs directly from the weighing table to the briner, where the cans pass the length of a galvanized 1-inch pipe about 5 feet long placed horizontally above the conveyor belt. On the under side of this pipe small holes are drilled at intervals of from one to two inches, through which hot brine is constantly running in small streams. By the time a can has passed the length of this pipe, it has been completely filled with brine. Any overflow drops into the brine box beneath. This box is about 4 feet long, 2 feet wide, and 2 feet deep. The brine is conveyed by gravity from large brine tanks through a pipe to the brine box. An automatic float valve admits the brine to the brine box as fast as it is needed. Inside the brine box, along one side, is a ½-inch steam coil which serves to keep the brine hot during packing operations. A small rotary pump elevates the brine from the brine box to the horizontal pipe above the conveyor.

Both wet packs and dry packs pass through the briner on their journey to the sealing machines, but, in the case of the latter, the rotary pump is disconnected from the power shaft, so of course no brine falls into the cans.

From the briner, the conveyor passes the cans to the sealing machine. These machines are automatic in their operation, throughout. The caps are placed on the cans; the tops of the cans have an outward flare, and, by the operation of 2 different rollers through which the head of the can passes, the outer edge of the cap is rolled around and under the flare of the can, enfolding it, and the two are then crimped together by an enormous pressure, which makes an air-tight seam. The can is then discharged from the closing machine to a conveyor, at the end of which a boy is stationed who takes the cans as they are delivered to him and places them in the process baskets.

The basket of cans is hoisted by means of the crane and lowered into the testing tank. The boiling hot water expands the air in the cans, pushing out the heads of the cans and making them convex. If any cans have been defectively closed, the leak will become apparent at once by the bubbles of air which are forced from the cans by expansion. If any such appear, they are removed, the cans opened and their contents returned to the packing table. Not every basketful of cans is subjected to this test for leaks. At the beginning of the day's operations the first basket of cans is always tested to make sure the closing machine is doing good work. At intervals during the day, the test will be repeated, and if too many leaks should materialize, the operator of the closing machine will endeavor to locate the cause of the faulty work and remedy it.

The process baskets, filled with cans, are lowered into vertical retorts, all being submerged in hot water. The lid of the retort is then fastened down steam-tight and live steam turned into the retort until a temperature of 240° F. has been reached, at which temperature they are held throughout the time they remain in the retort. In the case of wet packs, the No. 1 cans are processed for 12 minutes and the No. 1½ cans for 14 minutes. The dry packs are maintained at the same temperature for 60 minutes and 70 minutes respectively.

After processing, the baskets of cans are lowered into the cooling tanks, which are identical in size with the process retorts, but are made of wood and have no covers. The cans remain immersed in cool water in the cooling tanks for about 10 or 15 minutes, the object being to facilitate the handling of the cans.

As a rule, at least a week elapses after processing before the cans are labeled. By this time, if there are any defectively closed cans their contents will have begun to ferment and the labelers will be able to detect them from the appearance of the can. However, the percentage of leaks is extremely small, seldom being more than a small fraction of one per cent. At the time of labeling, the cans are placed in wooden cases, 4 dozen No. 1's or 2 dozen No. 1½ cans to the case, when they are ready for shipment.

No attempt is ever made to grade the meat placed in the cans; but if the shrimp on any particular day should be running small, the day's pack will be stored to itself and sold as small shrimp, bringing from 5 cents to 10 cents per dozen cans less than the rest of the pack. Such shrimp, however, constitute but a small proportion of the pack. Every effort is made to avoid the canning of small-sized shrimp; but it sometimes happens that the fishermen, after several day's run of poor luck, will strike a school of shrimp of questionable size and bring them to the factory. In such a case, the packer frequently has no choice but to accept them, to keep the fishermen in a good mood, although he will do so under protest and usually gives the fishermen warning that no more shrimp of that size will be accepted.

Drying.

A large portion of the shrimp caught in Louisiana in Barataria Bay and adjacent waters is marketed in dry form. Large wooden platforms are erected on which the green shrimp are spread out and sun-dried.

The drying platforms are erected near the water's edge, being made of cypress wood. They are built upon posts, standing 8 or 10 feet above the ground. One of the largest platforms on the bay is 230 feet long by 180 feet wide and has a capacity of about 1,000 baskets of green shrimp at one time, or 100,000 pounds. The floor of the platform, instead of being level, is gently undulating, having an ocean wave effect, the waves being about 2 feet in height and separated by a distance of about 30 feet from crest to crest.

The shrimp are brought directly to the drying platform by the fishing boats, where they are unloaded and washed and placed in large copper kettles. To each kettle of water, from 10 to 20 quarts of salt are added, depending on the weather; in damp weather more salt is required than in dry weather. After the water has been brought to a boil, the shrimp are dumped in, about 900 pounds to each kettle. They are then boiled for from ½ to ¾ of an hour. The method of judging whether the shrimp have been boiled long enough is to hold one up to the light and note the shrinkage of meat within the shell. A clear space of about ¼ of an inch between the back and the meat indicates sufficient cooking. Before each boiling, the same quantity of salt is added to the water; and after the fifth or sixth boil, the water in the kettle is entirely renewed and the process repeated.

After the shrimp have been boiled for a sufficient length of time, they are dipped from the kettles into wheelbarrows by means of a large dip-net, and after draining for about fifteen minutes, are hauled to the drying platform. Workmen now spread them out in a thin layer not more than 2 or 3 inches thick, with long wooden rakes. The thickness of the shrimp on the platform depends upon the quantity on hand at any one time, and they are never spread on the platform to the maximum depth unless the amount of shrimp on hand makes it necessary. Several times each day the shrimp are worked over with the rakes to facilitate drying. The frequency with which the shrimp are turned during the day depends upon their thickness. Where they are three inches thick, turning is required about every 20 minutes.

Every night, the shrimp are pushed and swept onto the ridges in long windrows. A-shaped trusses are placed astride each windrow of shrimp and covered with tarpaulins to keep off rain and dew. The tarpaulins must be so placed as to provide an opening at each end of the windrow to allow perfect ventilation, otherwise the shrimp would become heated and spoil. If the drying process is sufficiently well advanced, the trusses may be dispensed with and the tarpaulins spread directly over the shrimp, but in the earlier stages, ventilation is absolutely indispensable and the trusses must be used.

If the weather is good, the drying process can be completed in from one to two days, depending somewhat on the thickness of the shrimp on the platform. If a rain should appear to be coming up, the shrimp are pushed onto the ridges and covered with tarpaulins. No matter how hard it rains, they will not get wet, since the falling water all drains away from the ridges. As soon as the rain passes over and the sun comes out, the shrimp are again spread out and the drying process continued. It frequently happens, however, that a long period of wet and cloudy weather catches the men with a platform full of shrimp that are still quite green, and which spoil on their hands before favorable weather returns. But if the drying process is well advanced at the time the rainy weather appears, the shrimp can be stored in the warehouse and kept for many days, being returned to the platform and completely dried upon the return of clear weather.

After the drying process has been completed, the shrimp are pushed into large round piles on the platform and the workmen proceed to tramp the shrimp, going around and around the pile in a sort of a slow trot. This tramping or "dancing" process results in separating the heads and shells and legs from the meat, reducing them to what is known as "bran."

After being thoroughly "danced," the meat is separated from the heads and shells by means of a coarse wire screen of about one-quarter inch mesh.

No amount of "dancing" will detach every particle of shell from the meat, and so some firms give it a still further cleaning by placing it in sacks and beating with boards, after which it is again sifted. This produces a higher grade of meat which commands a somewhat better price. However, some platforms prefer the lower price to the additional labor of beating in sacks, and give the meat no further cleaning beyond thoroughly "dancing" and screening.

The shrimp meat is packed in large sugar barrels, about 230 pounds to the barrel. The "bran" is put up in burlap sacks and sold either as fertilizer or meal, about 30 sacks to the ton.

From a basket of shrimp, weighing 105 pounds, the dryers obtain from 12 to 14 pounds of meat. It has been found that the amount in weight of "bran" secured from a given quantity of shrimp is always practically the same as the weight of the meat.

The "bran" is sold, almost altogether, locally, very little of it being shipped any great distance. The Latin and Asiatic races consume by far the greater portion of the dried meat. A great deal of it is sold in the United States, but much of it is also exported to Central and South America, Cuba, Porto Rico, and the Hawaiian Islands.

In recent years, when there has been a shortage of stock feed, the use of shrimp bran as a feed was commenced. Various investigators have shown that it possesses high nutritive value and is, therefore, more valuable for meal than as fertilizer. It is fed to swine, poultry and other farm animals.

Chapter 30.

The American Crab Industry.

History of the Fishery.

The crab industry is one of the most modern American fishery industries. Although the edible qualities of crabs have been recognized for many centuries in Europe, the beginning of the important Chesapeake crab fishery was about 1873 or 1874 when the first soft crabs were shipped from Crisfield, Maryland. The industry grew slowly at first because of the unfamiliarity of the majority of the people with this sea food. By the year 1880, the annual production of crabs in the Chesapeake Bay had reached 3,305,867 pounds; in 1890, 9,469,313 pounds were sold, and in 1901 the production had reached 21,530,076 pounds. The present annual production is over 50,000,000 pounds of crabs.

4,075 cases of crabs valued at $32,780 were canned in Alaska in 1921. Only about 200 dozen were sold in the shell in this region. The latest available statistics relative to the production of crabs by states is presented in Table 72.

Species of Economic Importance.

The blue crab, *Callinectes sapidus,* is the most important American crab and is found on the Atlantic Coast from Massachusetts Bay to at least as far south as the northern part of South America. It is common along the United States coast from Massachusetts to Texas and is especially abundant in bays and at the mouth of rivers. Although its natural medium is salt water, it is sometimes found in brackish and even in fresh water.

Cancer magister is the common crab of the Pacific Coast; this crab is found from Lower California to Unalaska. Its favorite habitat is in shallow water on exposed sandy beaches or in sandy bays.

The rock crab, *Cancer irroratus,* is most common on the New England coast, but it is found from Labrador to South Carolina. This crab is not fished extensively although it is exceedingly abundant, contains more meat than the blue crab and is equal to the latter in flavor. Casco Bay, Maine, is the only place where many are caught.

The Jonah crab, *Cancer borealis,* resembles the rock crab, but it has a rougher shell with scalloped edges and is usually of slightly larger size. It is found in various localities from Long Island to Nova Scotia. The principal localities are Noank, Connecticut; off Watch Hill, Newport and Narragansett Bay, Rhode Island; Vineyard Sound, Noman's Land and Salem, Massachusetts; Casco Bay and the Bay of Fundy. It ranges in

TABLE 72

ANNUAL CATCH OF CRABS BY STATES

	Species	Year	Pounds	Value
Maryland	Hard	1920	5,165,703	$248,160
	Soft	1920	3,897,271	494,784
Virginia	Soft	1920	1,171,737	164,269
	Hard	1920	12,465,342	401,295
Washington	.....	1915	1,734,410	54,526
Massachusetts	Hard	1919	1,764,941	49,424
	Soft	1919	266	40
California	.....	1920	1,115,862	....
North Carolina	Hard	1918	145,605	1,983
	Soft	1918	233,705	23,821
Oregon	.....	1915	415,272	13,755
Texas	Hard	1918	193,244	10,672
	Soft	1918	700	175
Louisiana	Hard	1918	281,925	9,908
Mississippi	Hard	1918	216,025	5,607
	Soft	1918	9,000	2,275
Alabama	Hard	1918	95,850	3,292
Maine	Hard	1919	70,575	3,595
Florida	Hard	1918	52,000	1,800
	Stone	1918	24,500	206
Rhode Island	Hard	1919	34,330	1,802
Georgia	Hard	1918	8,455	504
South Carolina	Hard	1918	18,000	400
	Soft	1918	300	75

size up to about 6 inches across the shell. Its flavor is excellent but because of its limited distribution it has never been an important article of commerce.

The stone crab, *Menippe mercenarius,* ranges from North Carolina to Texas. It compares favorably in flavor with the blue crab and also grows to a much larger size than the blue crab. The principal fisheries are in Charleston, S. C., and Key West, Florida, but are not extensive because of the scarcity of this crustacean.

The king crab, *Lopholithodes mandtii,* is found on the Pacific Coast, but is now rare.

A list of crabs of minor importance is given below:

Fiddler crabs	*Gelasimus pugnax*
	" *pugilator*
	" *minax*
Green crab	*Carcinus mænas,* Leach
Hermit crabs	*Eupagurua bernhardus*
	" *pollicaris*
	" *longicarpus*
Horseshoe crab	*Limulus polyphemus*
Jonah crab	*Cancer borealis*
Kelp crab	*Epialtus productus*
Lady crab, sand crab, squeaker crab	*Platyonichus ocellatus,* Latr.
Mud crab	*Panopeus herbstii,* Edwards
Mussel crab	*Pinnotheres maculatus*

Oyster crab	*Pinnotheres ostreum*
Purple shore crab	*Heterograpsus nudus*
Red crab	*Cancer productus*
Rock crab	*Cancer irroratus*
Sand bug	*Hippatalpoida,* Say
Spider crabs	*Libinia emarginata,* Leach
	“ *dubia,* Edwards
Stone crab	*Menippe mercenarius,* Gibbes
Yellow shore crab	*Heterograpsus oregonensis*

Life History of the Blue Crab.

The young of the crab *Callinectes sapidus* are hatched from very small eggs about $\frac{1}{100}$ of an inch in diameter, which are carried by the female during the period of incubation attached to small hairs on the inner branches of the swimmerets on the under side of the abdomen. The eggs are yellow or orange when first laid but become almost black as hatching time approaches. The entire mass of eggs attached to the swimmerets of the abdomen is called a sponge; this contains according to Churchill,[1] from 1,750,000 to 2,000,000 eggs. These eggs hatch after about 15 days incubation. After hatching the young crabs pass through two free swimming stages; during the first stage the young crab is known as a zoëa and is much unlike the adult form. The body is somewhat cylindrical in shape, the eyes are large and conspicuous, the spines at the sides short; there is a long curved spine on the back; the claws are lacking. The zoëa has a long sharp beak, two pairs of antennæ, and four pairs of leg-like appendages. During this stage the young crab moults about six times.[2] During the second stage the young crab is known as a megalops. The megalops more nearly resembles the adult, having a rather flattened body and a shorter and wider abdomen than the zoëa. During this stage it swims freely but may also walk on the bottom. The megalops does not moult except to assume the true crab shape.

In passing from the megalops stage to that of the adult crab stage, the crab moults about 15 times at intervals averaging approximately 15 days during which it increases from $\frac{1}{25}$ of an inch in width to about 7 inches, increasing in width about $\frac{1}{3}$ at each moulting. Growth is rapid for the crabs mature and mate during the second summer at the age of 12 to 14 months. Mating occurs in the female at the time of the last moulting while she is yet soft. She is carried tightly by the male for a few days prior to such moulting and at this stage "doublers" or mating crabs are often caught on the trot lines. If mating occurs early in the summer, the eggs are laid about two months later; when the mating occurs in July or August the eggs are not laid until the following spring or summer. The female crabs may lay two or more batches of eggs during her lifetime. Most of the crabs live only three years although a few survive for four years.

Young crabs possess the power of regenerating a leg or claw lost or voluntarily thrown off. The regeneration is completed at moulting.

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[1] Churchill, E. P., Jr., *Bureau Fisheries Bull. 36* (1917-18), 91-128.

[2] Paulmier, F. C., *N. Y. State Museum 55th Ann. Rept.*, 1901.

Blue crabs are scavangers and cannibals, although they occasionally feed upon aquatic vegetation; their favorite food, however, is the flesh of dead and putrid animals.

In winter most of the crabs retire to fairly deep water. Formerly it was thought that they buried themselves in the muddy or sandy bottoms in the deeper parts of the bays and harbors, but now it is believed that most of them do not bury themselves but remain more or less inactive on the bottom.

Composition.

The composition of fresh and canned blue crab and of a Japanese crab is given in Table 73.

TABLE 73

COMPOSITION OF CRABS

	Refuse	Edible Portion	Composition (Edible Portion)					
			Water	Water Free Substance	Protein N×6.25	Ether Extract	Ash	Carbohydrates
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Fresh:								
Blue crab[a] (*Callinectes sapidus*)	55.84	44.16	77.07	22.93	16.64	1.96	3.13	1.20
Canned:								
Blue crab (*Callinectes sapidus*)	None	100.0	79.97	20.03	15.80	1.54	1.94	0.75
A Japanese crab (*Paralithodes camtschatica*) .	None	100.0	78.51	21.49	17.75	....	....	....

[a] Atwater, W. O., *U. S. Fish Comm., Rept.*, 1888, 679-868.

The Atlantic Coast Fishery.*

Location.

Commercial crab fisheries exist in every state along the Atlantic and Gulf coasts except New Hampshire and Connecticut. However in Maine, Rhode Island, South Carolina, Georgia and Florida, the industry is only of minor importance. The center of the blue crab industry, which is the major crab industry of the United States, is on the Chesapeake Bay. Maryland and Virginia produce approximately five-sixths of all the crabs caught in American waters. The importance of the Chesapeake Bay crab fishery overshadows the crab fisheries in all other sections of the coast. The Chesapeake Bay industry is centered in Somerset, Dorchester, Talbott and Anne Arundel counties in Maryland, and in Elizabeth city, Accomac, and Northumberland counties in Virginia.

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* This section is based chiefly upon information furnished by Dr. E. P. Churchill who studied the blue crab and its fishery for several years.

Seasons.

Soft Crabs.—Soft crabs are taken only during the warm months as the moulting of the young at the successive stages of growth occurs only during warm weather and therefore the soft crab season is during the late spring, summer and early fall. The season opens two or three weeks earlier in Virginia waters than in Maryland. The exact date of opening depends upon the weather. In early springs, soft crabbing in Virginia begins during the latter part of April. Soft crabbing usually is discontinued in Virginia about the first of August because of the very hot weather and the poor transportation facilities. But at Crisfield, Maryland, soft crabs are caught as late as the first or the middle of October.

Hard Crabs.—In Maryland the catching of crabs is prohibited by law between November 1 and April 30. In Virginia a few dredge boats operate during the entire winter. During cold weather trot-line crabbing is not practiced as the crabs are numb and inactive; this method of crabbing cannot be used after December 1. Since trot-line crabbing is a cheaper method of catching crabs than dredging, little dredging is done before the first of December.

Methods of Fishing.

Soft Shell Crabs.—The soft crab fishery is necessarily limited to the late spring, summer, and early fall months as soft crabs are obtained only as a result of the moulting of the young crabs which takes place only during the warmer months. Soft crabs are either caught in that condition or are obtained by holding a "peeler," or crab about to shed, until it moults. When a crab approaches the time of moulting, a narrow white line appears on the outer margin of the next to the outer segment of the fourth pair of legs or "back fins." In this stage, the crab is called a "fat," "green" or "snot" crab, and is not saved as it would be likely to die if held in captivity until it moulted. Within a few days the line becomes pink in color and the crab is known as a "peeler" by the crabbers. Peelers are saved and kept alive in live boxes and floats until they moult. The bulk of the soft crabs handled are obtained by the "shedding out" of peelers or crabs about to shed.

Soft crabs and peelers are chiefly caught in dip nets or in scrapes although a few are caught on the trot-lines. Trot-lines are used mainly for the catching of hard crabs since a soft crab cannot take the bait and peelers do not often bite as they eat little for a few days before they shed.

A dip net is a hoop of ¼ inch iron rod about a foot in diameter, carrying a net bag of 1 inch mesh, attached to a straight wooden handle about 7 feet in length. It is used by crabbers fishing in shallow waters in coves, inlets, mouths of creeks and in other places where the bottoms are not suitable for the use of the scrape. The crabber, reaching into the water from a boat, scoops up the soft crabs or peelers.

A scrape consists essentially of a triangular iron frame with a base varying in width from 2 to 5 feet attached to a cotton-mesh bag which extends about 6 feet behind. The scrape is similar to the oyster dredge except that it is lighter, has no teeth on the front bar and has a cotton instead of a chain bag. The scrape is dragged by a rope fastened to the apex. Small sailboats varying in length from 20 to 60 feet are commonly used for this method of crabbing. Usually one scrape is dragged on each side of the boat, but the larger boats use three and sometimes four scrapes. They are hauled in alternately by hand after covering 75 to 200 yards and the contents are dumped into shallow boxes attached to the side of the boat from which the crabs are sorted out of the mass of seaweed, shells, fish, etc., which is brought up by the scrape. The hard crabs are put into barrels and the soft crabs are kept in boxes.

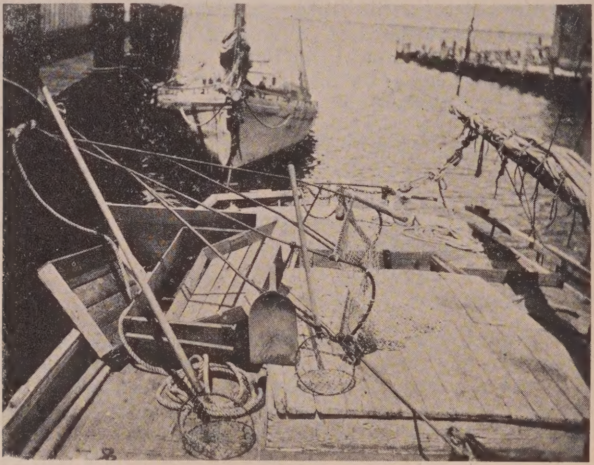

Photo by E. C. Cory.

FIG. 201.—Crab scrape on scrape boat.

Two men are required to handle a heavy scrape but the lighter scrapes are drawn up by a single man. With a good breeze a crew of two men can handle two light scrapes. In order to obtain good catches of crabs, the scrape must be dragged over the bottom slightly faster than the crabs can travel so that they cannot escape when once in the bag.

The crabber usually reaches the crabbing grounds at daybreak and returns to market his catch before noon, it being advantageous to sell the crabs before the heat of the day has injured those confined in the live boxes.

Since the practice of scraping is carried on in fairly deep water, and is confined to the Crisfield region where the immature crabs predominate in number during the season, the bulk of the catch consists of peelers, as the crabs move inshore just before shedding and consequently the soft crabs are more numerous in the shallower waters.

The heaviest catches of soft crabs are made during June and July. Crabs are caught by the use of the scoop-net throughout the season, but little scraping is done after the middle of July owing to the calm weather. Fishermen often scrape for crabs as long as there is sufficient wind to sail their boats, and, when the wind dies down, anchor their boats, and use their skiffs in scoop-netting in shallow water or on bottoms where the bottom grass grows so thick that scraping is impossible. In shallow water less than three feet deep the crabbers often leave their skiffs and wade for the crabs.

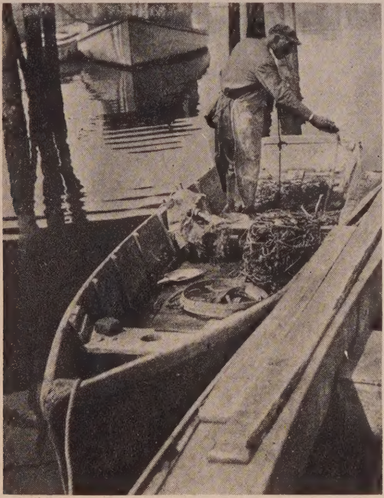

Photo by E. P. Churchill, Jr.

FIG. 202.—Rebaiting the trot-line and coiling it ready for the next day's work.

Hard Crabs.—The scrape, the trot-line and the dredge are used for the taking of hard crabs. Since crabbing with scrapes has already been considered above, further discussion is not necessary.

The trot-line is the most common instrument used for the capture of soft crabs; however, it can only be used when the water is warm, for during cold weather crabs do not seize the bait. Churchill[8] has described the use of trot-lines in the Chesapeake Bay in much detail as follows:

> The trot-line consists of a line varying in diameter from three-sixteenths to three-eighths inch, and in length from 800 to 2,000 or more feet. A weight is secured to each end to hold the line in place while on the bottom, and a buoy to mark the spot is attached near the weight by a short drop line. In some cases the baits are suspended to the line by snoods 6 to 8 inches in length. This is the usual practice where no power or sail boat is used, the lines being "run" by hand—that is, the boat is pulled along the line by hand. In other cases the baits are secured in bights in the main line. This is done when the line is run by a power or sailboat. In this case the line passes over a spool or an oarlock set on an arm

[8] *Bureau Fisheries Rept.*, 1918, Appendix 4; also ibid. *Doc.* 868.

projecting about 1 foot from the side of the boat. As the boat is moved along, either by hand or by the engine or sails the line is lifted and the crabber catches the crabs in a short-handled dip net, as they are brought to the surface while clinging to the bait. At Phoebus, Va., a patent net is used by some crabbers. This is attached to the side of the boat by an arm and secures the crabs as the line passes through it. When not in use the arm may be raised and the net thus suspended over the boat. In hot weather the crabber often reaches the crabbing grounds at 3 or 4 o'clock in the morning. Crabs are thought to bite more readily in the early hours and the catch can be delivered to the dealer before the heat of the day, and consequently less risk of the crabs being killed by the heat is incurred. The line is set each morning and lifted when the catch is completed. It is coiled temporarily in the boat until the crabs are unloaded at the crab house. Then it is gone over carefully and any empty snoods or bights are rebaited and the line carefully coiled in the stern of the boat, some salt is sprinkled over it to preserve the bait, and the whole covered with a rubber sheet, old blanket or the like for the night. The bait commonly used is inedible beef or sheep tripe, some horsemeat, eels, skates, etc., being used in the spring when the crabs are not so active and consequently do not tear the bait to pieces so readily. A good day's catch with the trot-line is three to four barrels when the line is run by hand and twice that when run by power or sailboat.

Most of the soft crabs obtained by use of the trot-line are those resulting from the "shedding out" of the female peelers of the pairs of mating crabs or "doublers." The male carrying the female, seizes the bait and is drawn up, and both are caught.

In winter, when most of the crabs retire to deep water and either partially bury themselves in the sand or lie inactive on the bottom, they are captured only with dredges. The boats used in dredging crabs are about 50 to 60 feet in length and are sailboats equipped with auxiliary engines. The dredge resembles in many ways the scrape although it is much larger and has a row of teeth about four inches long on the bottom. Its length varies from 5 to 7 feet and the bag is usually only about 2 feet in length. The lower part of the bag is constructed of iron meshing, the upper of cotton. A dredge is usually dragged from each side of the boat by means of a chain about an inch in diameter which passes over a roller and around a pulley attached to a stout post placed upright in the mid line of the boat and thence down and around a windlass in the hold. The two windlasses are operated by the engine controlled from the pilot house. The dredges are hauled in alternately and their contents are dumped on deck. Two men are required to handle the dredge, one working forward, the other aft of the dredge. The crabs are raked from the debris by small hooks or the hands, culled, and shoveled into barrels. The debris is thrown overboard. The average catch of crabs by the dredge boats is about 10 barrels; from day to day the catch varies widely. Catches as large as 50 barrels are occasionally reported.

Formerly few crabs were caught in the Chesapeake Bay in winter but in recent years many dredge boats have operated throughout the winter and therefore several picking houses have remained open all winter.

Marketing.

The larger boats, as the scrape boats and dredge boats, which are equipped with sails or power or both, usually deliver their own catch directly to the crab house. The smaller crabbers and those operating in isolated regions sell their catches to buyers who make regular trips in boats called "run boats" or "buy boats." A "run boat" is one whose captain is merely the agent of a dealer and works on a commission, whereas if the dealer operates his own boat it is called a "buy boat." In addition to buying crabs these boats usually sell bait. Most of the dealer's boats in the Chesapeake Bay operate from either Crisfield, Maryland, or Hampton, Virginia.

Preparation for Market.

Soft Crabs.—The crab houses which handle soft crabs and peelers are known by the trade as "shanties," "shedding houses" and "soft crab houses." These houses are usually small wooden buildings built on pilings over the water. The peelers are put into floats tied to stakes in the water nearby and left until molting occurs, when the resulting soft crabs are removed and packed for market. The floats commonly used in the Crisfield region are constructed of pine or cypress and measure about 4 by 12 feet by 15 inches in depth. The sides are constructed of laths, placed vertically with one-fourth inch spaces between them. The bottoms are made of 6-inch boards and are continuous. In order to support the structure evenly on the water an 8-inch wooden wing is constructed around the outside of the float halfway from the top. In other sections of Maryland, other styles of floats are used but they differ from those described above chiefly in size and depth.

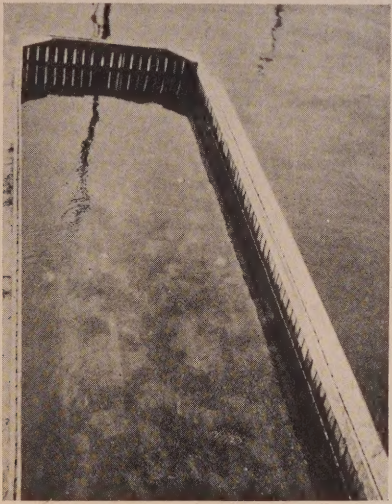

Photo by E. P. Churchill, Jr.

FIG. 203.—Float in which crabs are allowed to shed.

When the crabs are placed in the floats they are sorted into various lots. "Green" peelers which will not shed for several days are placed in certain floats; crabs in the more advanced stages are put in others, while the shedding floats are filled with "rank" peelers or crabs actually shedding or about to do so. A "buster" is a crab in which the back shell has cracked loose from the apron and will complete the process of shedding within an hour or so. The crabs are not fed during their confinement in the floats. Many of them die, the proportion dying depends upon the weather. If the temperature of the water is high one-third or more die.

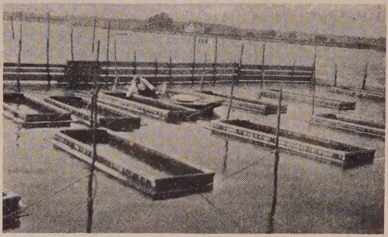

Photo by E. P. Churchill, Jr.

FIG. 204.—"Fishing out" the soft crabs from a float. This is done about three times a day.

A freshly moulted crab is very soft and dies very quickly if shipped, and therefore the crabs are allowed to remain in the floats for a few hours after shedding before being removed for packing. The soft crabs are "fished out" of the float by means of a small, shallow hand net about three times each day. If they are not removed for 48 hours after moulting, the new shell will have become too hard for commercial use as a soft crab, for a tough leathery shell will have formed. Such crabs are called "buckrams" and are sometimes sold but they are of little value for culinary purposes as their tissues are watery and contain little meat.

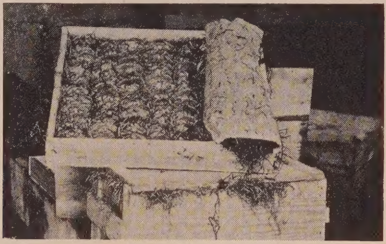

Photo by E. P. Churchill, Jr.

FIG. 205.—Tray of "cull" soft crabs, parchment paper and seaweed covering rolled to one side.

Soft crabs are always shipped alive. Before shipping they are sorted into four grades or sizes. The smallest of these is the grade "culls" which average about 3½ inches in width. "Medium" crabs vary from 4 to 4.5 inches in width; "prime" crabs range from 5 to 6 inches; and "jumbos" are those above 6 inches in width. The primes are the most valuable grade. The sizes given above are not fixed but vary somewhat depending upon the packer, the quantity of the catch and the state of the market. In shipping to some markets, the large crabs are not graded as jumbos but are included with the primes.

Great care is used in packing soft crabs for they must reach their destination alive. They are packed in shallow wooden trays about 3 or 4 inches in depth. Each tray is of sufficient depth to accommodate but one layer of crabs. A layer of seaweed is spread over the bottom of the tray and the crabs are placed on it in rows inclined at an angle of about 60° as shown in Fig. 205. The crabs live longer in this position than if lying flat as the water does not run out of their gills so quickly. A sheet of parchment paper is placed over the crabs and this is covered with seaweed and cracked ice. Two or three trays of crabs are placed in a crate. The most common size of crate is one which holds about 15 dozen prime crabs and weighs about 80 pounds when packed with ice. Most of the crabs reach their destination alive except in hot weather when a number die if they are transported long distances.

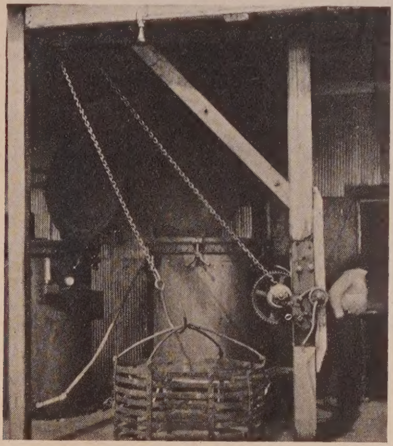
Photo by E. P. Churchill, Jr.

FIG. 206.—Usual style of crab steamer, basket and crane.

Hard Crabs.—Some hard crabs are shipped alive in barrels with ice. The large whole crabs, called "Jimmies," are usually selected especially for these shipments. A few steamed crabs are shipped whole on ice but the great bulk of the hard crab catch is steamed, the meat picked out and shipped on ice or canned.

The first operation in the preparation of crab meat is the steaming or cooking of the crabs. One of the most up-to-date methods of cooking crabs is to place the crabs in circular iron framework baskets about 3 feet in diameter and 16 inches in depth. Two or three such baskets are hoisted into a cylindrical metal tank of slightly greater diameter by means of a hand operated crane. A heavy iron lid is clamped on the tank or cooker and steam is passed into it for about 25 minutes.

One Virginian "crab factory" places the crabs in iron framework cars about 7 feet long, 2 feet deep and 2 feet wide, which are run on a track into rectangular horizontal cookers which hold two cars.

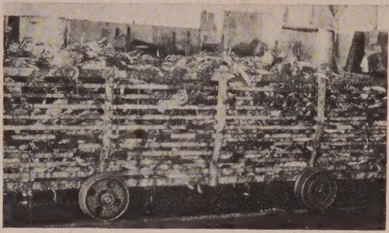

Fig. 207.—Car of steamed crabs.

Churchill has described various other forms of cookers used in Maryland:

> One of the commonest sorts is simply a box made of pine boards from 1 to 2 inches thick. The box is usually about 8 feet in length by 4 in width and depth. A grating made of wooden slats is placed about 4 inches from the bottom of the box. This holds the crabs up off the bottom and allows the steam to have free access to them. No baskets are used, the crabs being dumped directly into the box. Steam is admitted through a pipe from the boiler, the pipe entering the box near the bottom at one end. A lid of planks covers the box during the cooking. Small holes in the bottom allow the escape of the water from the condensed steam. After the cooking is completed, the box is turned upon one side by lifting on a wooden bar running along the side, and the crabs dumped out upon the floor of the cooking house. In some cases there is a door along one side of the box near the bottom to allow the crabs to be removed without having to turn the entire box over. In other cases there are two large wooden rockers under the box and two on the side. During the steaming the box is kept steady by blocks placed under the ends of the rockers. When these are removed the entire cooker may easily be rolled over on to the rockers on the side and propped in a sloping position with the top lower than the bottom. The crabs can then be removed readily.
>
> Two firms at Annapolis, Md., use cookers made from wooden barrels. Two or more barrels are connected with the steam pipes in such a way that each may be operated independently. The pipe enters the side of the barrel (which stands upright) near the bottom and branches into the form of a U. Numerous openings along the U permit the exit of the steam. There are small holes in the bottom of the barrel to allow the water from the condensed steam to drain out. The crabs are placed directly in the barrels, no baskets being used. A gunny sack is placed over the top and on this the barrel lid. A bail and a hand-operated crane admit of the barrels being lifted independently and swung over the picking tables, where the crabs are dumped.

The steaming kills the crabs and cooks the meat; the shells change from blue to a bright red color.

The cooked crabs are dumped on the picking tables where the back shells are removed and the meat is picked out from the body of the crab by means of a sharp-pointed knife. The pickers are paid according to the amount of meat prepared. An experienced picker can remove from 60 to 70 pounds of crab meat in a day.

The pickers divide the meat into three grades depending upon the region of the body from which it is taken. The "lump" meat, which is that from the muscles which operate the swimming legs or back fins, is considered the best. The "white" or "flake" meat is made up of the remaining muscles of the body with the exception of the claws, and ranks next in value. The "claw" meat brings the lowest price because of its dark color. Many persons, however, prefer its flavor to that of the other grades. The three kinds of meat are packed separately in tin cans, with perforations in the bottom, which hold from 1 to 5 pounds. These cans of meat are packed in barrels with ice before shipping by express.

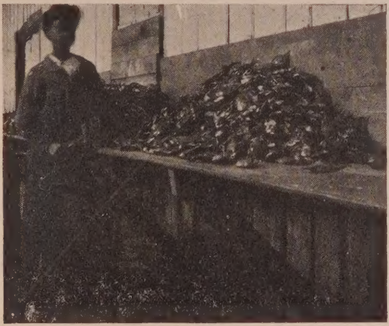

Photo by E. C. Cory.

FIG. 208.—"Knocking out," or making the preliminary cleaning of the shells.

A gallon of meat weighs about 5 pounds. The amount of meat obtained per barrel of crabs depends upon whether they are "fat" or "poor." In the spring and early summer, the muscles are shrunken and the crabs are called poor. In late summer, fall and early winter, the muscles are full, the crabs being called fat. Fat crabs yield about 20 pounds of meat per barrel, whereas poor crabs give only about 15 pounds of meat per barrel.

Some clean back shells are shipped with the cans of meat for use in the preparation of deviled crab. The shells are first "knocked out," by which process the portions of the reproductive organs and liver (which are popularly called "fat") adhering to the shells are removed. The shells are then placed in large wire crates or baskets and washed. The washed shells are dried by spreading either on a floor or wharf, or in shallow trays about 10 feet long by 4 feet wide consisting of a frame of narrow boards with a bottom of chicken-wire fencing.

Pacific Coast Fishery.

The edible crab, *Cancer magister*, of the Pacific Coast, is found from Unalaska to Magdalena Bay, Lower California. The most important fishery is at San Francisco; other important fisheries are located at Eureka, California; on the Puget Sound, Washington; and at Wrangell and Petersburg, Alaska. In Oregon, crabbing is carried on extensively at Coos Bay, Yaquina, and about the mouth of the Columbia. In British Columbia, this fishery is carried on at Boundary Bay, at Prince Rupert and on a smaller scale at many other points.

As the flesh of this crab undergoes changes at the moulting time that make it undesirable for food unless it is taken in the full soft-shell, and, since, by the methods used it is never taken in this condition, for the moulting individuals are not attracted by bait, soft crabs are not found on the Pacific markets.

The California laws forbid the taking of crabs from August first to November fifteenth inclusive, and the taking of crabs smaller than 7 inches. The legal size is 6½ inches in Washington and 6 inches in Oregon and British Columbia. The closed season in Oregon and Washington extends from July first to September thirtieth. British Columbia has no closed season and Alaska has no restricting regulations regarding crabs.

Methods of Fishing.

At Eureka and San Francisco, California, where the fishing is done chiefly in exposed waters off the harbors, hoop nets are exclusively used. These nets consist of two iron hoops connected by netting to form a basin shaped receptacle, which lies flat on the bottom when fishing, from which the crab cannot crawl; 15 to 25 of these are baited and set on a long rope in line with the run of the tide. About every hour the nets are hauled up and the catch removed. The hoop nets are usually hauled up and taken ashore at night.

A pot or trap similar to the lobster pot used in Maine is used in sheltered bays and sounds. Gray[4] has described the traps used in the Alaskan fishery and the method of fishing as follows:

> Crabs are caught in traps made of iron rods forming a framework that is covered with wire netting, except the ends, which are equipped with linen or cotton web tunnels through which the crabs may enter. The traps, which are about 40 inches long, 30 inches wide, and 20 inches deep, are baited with fish or salmon-cannery offal and set during the summer in water from 2 to 8 fathoms deep, and in winter to depths of 25 fathoms. The traps are lifted at frequent intervals and the catch removed and sorted. Only crabs measuring 6 inches or more in breadth are saved. The others, which include all females, are released. The larger ones are placed in a live-box and taken to the cannery. Crabs will live out of water for about 12 hours if kept in a cool place, and if kept in sea water they will live much longer. They feed on dead fish, animal matter, and such marine forms as they can catch. Moreover, they are cannibalistic and often kill and devour their own kind. If crabs of different sizes should be placed in a small tank, it would not be many days before there would be but one left, and it, the largest of the lot, the others because of their lesser size having become the legitimate prey of the largest one.

Owing to the limited demand for live crabs in Alaska, the bulk of the catch is canned and shipped to the United States.

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[4] *Bureau Fisheries Rept.*, 1922, Appendix 10, 46-48.

Most of the crabs caught in California are sold in San Francisco. Portland, Seattle, and Tacoma are other important crab markets on the Pacific Coast.

The Canning of Crab Meat.

For several years but one firm has packed (processed) blue crab meat. This concern, which is located in Hampton, Virginia, has successfully kept its process a secret. Various crab factories along the Bay have attempted to can the meat but none have continued to operate. Bitting [5] described a method of canning crab meat, but this procedure has not continued in use.

Some crabs were canned in Maine in 1922 but the industry is not yet firmly established.

Cobb [6] has described methods of canning the Pacific crab, *Cancer magister*, that have been developed at the College of Fisheries of the University of Washington.

> Some packers kill crabs by cutting their throat with a knife and allowing them to bleed thoroughly. The majority, however, put them alive in fresh water which has previously been brought to a jumping boil and in which has been dissolved one pound of bicarbonate of soda to 25 pounds of crabs. Here they are cooked for about 20 minutes (the length of time varies somewhat with the size of the crab; the larger requiring longer time than the small ones), after which they are taken out, washed in cool water, and allowed to cool.
>
> The back shell is first removed, when the body is washed under a stream of water. The meat is then removed from the crab, care being taken to see that none of it comes in contact with wood, after which it is washed in cold 1 per cent brine (one pound of salt to 12½ gallons of water), drained, and pressed to remove excess moisture. It is then packed in cans lined all around with parchment paper (some use cans which in addition have been enameled on the inside, but this is not absolutely necessary) with the addition of enough salt to flavor. Claw meats should be packed at the bottom and top of the can, and the center filled with body meat.
>
> The tops are then put on loosely and the cans exhausted for about 8 minutes at 212° F. The tops are then sealed, the cans put back in the retort, and given a cook for 40 minutes at 15 pounds pressure for ½-pound cans. The cans are generally cooled in the retort before removal. Some canners insist that it is necessary to lay the cans on their side while being cooked.

Gray [4] has described the methods in use in the Alaskan canneries in the following manner:

> When the crabs are delivered at the cannery, they are first placed in boiling water for about 15 minutes, after which they are taken by the sides and struck across a sharp edge of wood along the center of the back, thus breaking them into two pieces. The digestive organs are then removed and the meat is washed clean, preparatory to its being picked out of the shell and packed in half-pound cans lined with oiled paper. The body and leg meat is placed in the cans in alternate layers, and when the cans are filled the edge of the paper lining is folded over the meat so that the meat does not come in contact with the tin. The cans are next put through the capping machine, which caps and seals them, and then into the retort for cooking, which requires 50 minutes. When prepared

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[5] *U. S. Dept. Agr. Bull. 196,* Professional Paper (1915).
[6] *Pacific Fisherman, 19* (1921), No. 6, 14.

for shipment a case of crabs contains 48 one-half pound cans. The average amount of meat from a 6 to 9 inch crab is a little less than 8 ounces.

By-Products.

The "scrap" (waste shells left after the picking of the meat) is sold to fertilizer factories at a small price.

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Chapter 31.

The Lobster Fishery.

Early History of the Industry.

The early Puritan settlers on our New England Coast who were familiar with the European lobster soon recognized the value of the American lobster fisheries. In colonial times practically all of the lobster catch was consumed locally as there were no large inland cities, and as, moreover, the fishermen had no means of rapidly transporting their lobsters to distant markets. Practical methods of canning were not known at that time. As a result of these conditions, the lobster fishery of New England was largely limited to a few sections of the coast until about the year 1840 when rapid development commenced, as a result of the great improvement in transportation facilities and the discovery of commercial methods of canning. The lobster fisheries of the United States reached their greatest extent, considered from the standpoint of quantity taken, about the year 1892 when 23,724,525 pounds of lobsters valued about $1,062,392 were sold.

Location of Present Industry.

Cape Cod was one of the most important centers of the early lobster industry. But since about the year 1870, Maine has been the foremost state in the production of lobsters. Massachusetts comes second; Rhode Island third; Connecticut fourth; and New Hampshire fifth. Canada is the most important lobster producing country in the world and its product exceeds that of all the rest of the world combined. The Canadian lobster fishery is largely centered in Nova Scotia. All the lobsters caught in the United States are consumed fresh and none is canned, but in Canada the value of the canned lobsters packed exceeds that of the lobsters consumed fresh. The greater proportion of the Canadian lobsters which are not canned are exported to the United States. Newfoundland is also an important center of the lobster industry. The European lobster industry is located chiefly in Norway, Ireland, Scotland, England, Sweden and France. During recent years the European lobster industry has declined so rapidly that it is now of minor importance. The most accurate figures available regarding the world's annual lobster catch are given in Table 74.

The Decline of the Fishery.

In the early days of the American lobster fishery, these crustaceans were very plentiful and consequently were very cheap. They were much

TABLE 74

COMPARATIVE QUANTITIES OF LOBSTERS TAKEN ANNUALLY IN THE VARIOUS IMPORTANT LOBSTER PRODUCING COUNTRIES IN THE WORLD*

Country	Number of Lobsters
Canada⁺	70,000,000 to 90,000,000
United States⁺⁺	10,000,000
Newfoundland	6,000,000
Ireland	1,264,000
Norway	1,249,000
Scotland	712,000
Sweden	612,680
France°	605,000
England	546,800
Denmark	28,500
Netherlands	7,456
Germany	7,000

* Cons. Perm. Internat. pour l' Explor. de la Mer, *Bull. Statisque des Pêches Maritimes, 6* (1909).

° The returns for France include the "Langouste" or crawfish of the sea (*Palinurus*), as well as the true lobster (*Homarus*).

⁺ In 1909 Canada produced 34,580,600 lbs., valued at $5,388,343.

⁺⁺ Statistics for 1919 by states are given on page 586.

in evidence along the shore after storms, during which many were killed and washed upon the beaches. When plentiful they were commonly taken by gaffing from small boats, but such methods were discarded long ago, because of the growing scarcity of lobsters. As the number of lobsters taken has declined, the price has rapidly advanced. Prior to the year 1860 large lobsters were often retailed at 5 cents each; similar lobsters now bring from 50 to 75 cents. In the year 1888 the average annual catch per pot in Massachusetts during the season was 81 lobsters over 10.5 inches in length. By 1905 the average annual catch per pot had declined to 31 lobsters above the 10.5 inch gauge. No comparative figures are available for more recent years but the decline has continued. It is evident that the American lobster is in grave danger of extermination.

Since the Canadian and Newfoundland lobster fisheries have been developed more recently than those of the United States, these fisheries have not as yet been depleted to a similar extent. However, the annual catch is undergoing a rapid decline. At the height of the Canadian industry, the annual catch was approximately 200,000,000 lobsters, but in 1920 it was only about 40,000,000.

Conditions have been much the same in Europe. When intensive fishing was commenced the lobsters were rapidly depleted, until at present lobster is a luxury. The Norwegian lobster fishery reached its height in the year 1865 when 1,956,276 lobsters were caught. Recently the high price has greatly augmented the numbers of the Norwegian fishermen; because of this the size of the catch has not yet decreased to any considerable extent but it is doubtful if the natural increase of the lobster will be sufficient to permit the more extensive fishing for an extended period.

Life History of the Lobster.

The Larval Stages.

Since the American lobster (*Homarus americanus*) is the most important crustacean utilized commercially, and because of the rapid decline of this important fishery, many researches relative to its physiology and propagation have been carried out. The life history of the lobster is unique in many respects and is one of the most interesting studies in marine biology.

The great majority of the lobsters reach sexual maturity when about 10 inches long, but a few spawn when they reach a length of 7 inches. The number of eggs in the first litter varies from about 3,000 to 9,000. Most authorities agree that the American lobster spawns once every two years, and that the lobsters continue to grow until they reach a length of over 20 inches; the greatest recorded length being 23.75 inches and the greatest weight 34 pounds. The largest specimens captured invariably proved to be males. The number of eggs laid increases rapidly with the size of the animal. The eggs are usually laid during July or August, although they are often laid later in the year. The eggs are extruded at one time, and are not discharged into the sea water to float about until they hatch as is the case with fish spawn, but become attached to the swimmerets on the underside of the mother's tail by a glue or cement of unknown composition which is excreted simultaneously with the spawning. The eggs remain attached to the swimmerets and gradually develop for 10 to 11 months, at the end of which period the eggs hatch gradually. The hatching period usually extends over a week.

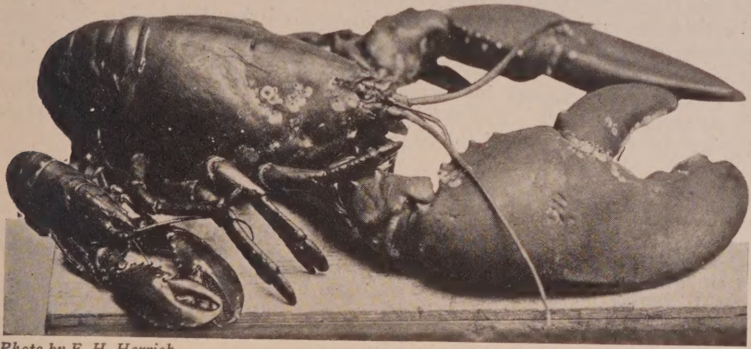

Photo by F. H. Herrick.

FIG. 209.—The larger lobster weighed about twenty-five pounds and the smaller one about two pounds. Lobsters weighing over ten pounds are seldom caught.

The newly hatched larval lobster possesses a short shrimp-like body and ringed tail stretched out almost horizontally. The larva is of glassy transparency, with gleaming emerald eyes, and possesses a huge pointed snout or rostrum. Two pairs of very short horns protrude in front (*antennæ* and *antennulæ*), the second pair being forked. Four of the six tail joints bear spines, two on each side, and one in the middle standing erect. The yellow liver is plainly visible through the translucent shell. The third pair of foot-jaws and five pairs of legs bear paddle-like outer branches, by the rapid movements of which the larval lobster swims aimlessly about, at a moderate speed, with the head commonly directed downward and the body usually bent in quadrant form. The direction is at first aimless, but certain influences such as light and food may cause it to become directive. At this stage the larva is about ⅓ of an inch in length from the tip of the snout to the end of the tail.

During the first two weeks of its existence, the larval lobster moults three times, changing slightly in appearance after each moult. The life of this crustacean is made up of a series of stages each of which represents the time passed between successive castings of the shell. The first four periods, during which growth is most rapid and the changes most pronounced, are passed rapidly. After this, and particularly after the sixth or seventh moult, except for increase in size there is little apparent change from moult to moult. Prince[1] has summarized the changes taking place during the development of the larval lobster in the following way:

> During the second week after hatching 5 changes may be noted: (a) the snout becomes toothed and is less blade-like in character; (b) paired swimmerets grow out along the underside of the tail—the second to the fifth tail rings; (c) green colour appears along the back region. The length increases by nearly one-twelfth of an inch, and the larva is now nearly half an inch long (9.50 to 11.1 mm.).
>
> (3) During the third week the principal change is the development of the nipperclaws or chelæ. All the feet hitherto were adapted for swimming and the first pair (or nippers) differed little from the rest; but at this stage they become proportionately much larger and their inner margins exhibit serrations or tooth-like projections. The eye still shows a bright metallic lustre, and green spots distinctly appear in the thin shell mingled with a brown coloration. This stage appears to rarely last more than a week.
>
> (4) The fourth or fifth week witnesses further changes. In outline the small lobster shows a resemblance to the adult lobster greater than it has hitherto exhibited. It has, after moulting, increased in length, and measures more than half an inch (13 to 15 mm.). The erect spines down the back have gone, while a deeper colour, brown or green, extends over the shell, and the nipping claws are of a warm brown or reddish colour.
>
> (5) The young lobster, six weeks to two months old, still swims about actively near the surface. Though its prevailing reddish brown tint renders it less conspicuous than in its younger stages when its glassy translucency is more marked, yet it is really a small insignificant object ¾ inch to ⅔ inch long, and not readily distinguished from the small fishes, young cod, gurnard, sculpins, etc., which abound in the same surface waters. A young lobster at this stage is often mistaken for a larval gurnard (*Prionotus*), as both swim rapidly forward in a similar way, and the moving reddish claws of the lobster bear no little resemblance to the orange tinted pectoral wings, or fins, of the minute gurnard. The snout is narrower and therefore appears more prominent and pointed, while the feathery outer joint or exopodite of the swimming feet becomes much diminished. This last feature, with the loss of the glassy translucency, characteristic of previous stages, indicates that the young lobster is about to take to the bottom.
>
> (6) One or two weeks later when the lobster measures a fraction more in length (15 to 17 mm.) it changes its swimming pelagic habit and comes inshore.

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[1] *Dominion Shell-Fish Fishery Commission, Rept.* 1912-1913.

Its colour is darker than hitherto, though there is great variation in this respect. Dark green, pale bluish or greenish brown are most frequent. As Professor Herrick points out, there appear at this time on the head shield two white spots, really points of internal attachment for tendons, very apparent a little behind the eyes The projecting edge (pluron) on each side of the first tail ring is also white. The snout or rostrum measures about one-quarter of the length of the head shield (or cephalothorax).

(7) During the third month of larval life which Herrick divides into two stages, the changes are mainly internal, and only the trained specialist is able to notice the slight external modifications which take place. The most important point is the assumption of the external characters of sex. The males and females, in early larval stages, cannot be distinguished. Up to the sixth or eighth week the first pair of swimmerets beneath the tail are mere rounded tubercles, and up to the stage now described the oviducal openings on the second pair of walking limbs are not apparent in the female. They now appear distinctly, and from this stage are mainly connected with growth and increase in size. The young lobster thus passes through changes in its early life of a very striking character. In outline it changes less, no doubt, than the shore crab, but in habits, mode of progression, food, etc., the changes are momentous. From a free swimming, almost transparent, mite in the open sea, it becomes transformed into a heavy opaque bottom-living scavenger. As the length of ⅘ of an inch is approached (19.5 or 20 mm.) the eyes begin to grow more rapidly and during the stages immediately subsequent are unduly prominent. This in fact is true of young marine larvae generally. Of course young lobsters, like other developing aquatic organisms vary in rate of growth and features of colour, etc., but the foregoing brief sketch may be said to represent the average larval life of the lobster. As in its mature adult stage so in its early days its food is varied. Minute marine plants, algæ, diatoms, as well as minute crustaceans, copepods or water fleas, etc., chiefly constitute its food. Larval lobsters feed chiefly at night, hence their illimitable myriads are not readily noted by fishermen or sailors; but on bright sunny days they rise to the surface of the sea. Light has a fascination which is common to many creatures in the water.

Habits of the Adult Lobster.

The sea bottom is the natural abode of the adult lobster, the source of its food and the scene of all its activities. It never forsakes the water or leaves the bottom of its own accord. Lobsters wander close to the shore and out to depths of over 100 fathoms in search of prey. In traveling over the bottom the lobster walks nimbly upon the tips of its slender legs; but when transferred from sea to land it can only crawl in vain attempts to walk, owing to the greater weight of its body, which the slender legs are unable to sustain. In the water the lobster is agile, wary, pugnacious, capable of defending itself against its enemies, and sometimes moves at a high rate of speed.

Lobsters do not migrate up and down the coast at definite periods or in considerable numbers, as do many fishes and birds; but in the spring they come in closer to the shore and in the fall they retire to deeper water. The optimum temperature of the lobster lies between 50° and 60° F.

The lobster is essentially a creature of nocturnal activity; it is generally far more active at night than by day. Adult lobsters dig up the sea bottom in their search for shellfish, and often cover themselves with mud during cold weather.

Lobsters are great scavengers and live chiefly on fish, alive or dead, and on the invertebrates which inhabit the bottom and come within their reach. They catch many small live fish and a few of the more sluggish larger fish. Adult as well as larval lobsters are cannibalistic and when crowded together quickly destroy each other.

The Color of the Lobsters.

Normal adult lobsters are dark green. The hard shell is an opaque lifeless substance; its characteristic coloring is caused by pigments which are excreted by the chromatoblasts of the soft underlying skin. These are immediately exposed upon removing the shell, and the delicate skin underneath is seen to be flecked or mottled with scarlet. The excreted pigments undergo physical and chemical changes in the hard cuticular shell and may thus become a decidedly different color from the parent chromatoblasts. Upon dehydration, oxidation and other chemical changes, the pigments of the lobster shell, due to the presence of chromogens, become converted into a red lipochrome resembling rhodophan. This accounts for the wonderful change of color which the lobster undergoes when boiled.

Propagation of Lobsters.

Need of Artificial Propagation.

Since the natural rate of multiplication of the lobster is unable to keep up with the extensive fishing now carried out along the Atlantic Coast it is evident that either protection or artificial propagation is required to maintain their numbers at the present level. Both means of increasing the lobster fisheries have been tried, but for various reasons neither has been very successful. Many protective laws have been enacted in the States possessing important lobster fisheries and in various European countries. In some localities closed seasons for lobster fishing have been enforced. In the maritime provinces of Canada there is a closed season for lobsters from June 30th to January 14th. New York, Rhode Island, Massachusetts and Connecticut have forbidden the taking of lobsters under 9 inches in length. Maine and New Hampshire have placed the legal length at 10½ inches, and in Norway and England the minimum length is 8 inches. In Canada the minimum limit is 8, 9, and 10.5 inches in different districts. In many places the laws have forbidden the taking of egg-bearing lobsters. Unfortunately, these laws have been very difficult to enforce and the fishermen have seldom deigned to obey them. As the older and larger lobsters are much more prolific egg layers, it is probable that a double gauge or length limit should be adopted. This would not only protect the younger lobsters but also the larger adults and would insure a continuous supply of eggs. Herrick has suggested that all lobsters under 9 inches and over 11 inches in length be protected by legal measures. Other measures suggested by Herrick[2] are the following:

2. Protect the berried lobster on principle, and pay a bounty for it, as is now done, whether the law is evaded or not, and use its eggs for constructive work, or for experimental purposes with such work in view.
3. Abolish the closed season if it still exists; let the fishing extend throughout the year.

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[2] *Bureau Fisheries Bull. 29* (1909), 149-408.

4. Wherever possible, adopt the plan of rearing the young to the bottom seeking stage before liberation, or cooperate with the United States Bureau of Fisheries, or with sister states to this end.

5. License every lobster fisherman, and adopt a standard trap or pot which shall work automatically, so far as possible, in favor of the double gauge, the entrance rings being of such a diameter as to exclude all lobsters above the gauge, and the slats of the trap of such a distance apart as to permit the undersized animals to escape.

Methods.

The artificial propagation of lobsters was first successfully carried out by Guillon and Coste [3] in 1865. Since that time many attempts have been made to rear lobsters from the eggs but until the year 1905 none was successful on a large scale. In that year, experiments on the culture of lobsters in agitated sea water, which were being carried out by Bumpus and Mead, had progressed far enough to leave little doubt of their success. By this method nearly half of all lobsters hatched can be successfully carried to the fourth stage, or the stage at which the young lobsters begin to seek the bottom and are better able to take care of themselves. Mead [4] found that, in order to insure success, the hatcheries must be located far enough off-shore to insure an undiminished supply of fresh sea water; he therefore located the experimental hatchery of the Rhode Island Commission of Inland Fisheries on pontoons anchored a short distance from the shore at Wickford, R. I.

The method consisted essentially of confining the larval lobsters in cars, either constructed of porous material or provided with screened openings, set into the ocean itself, and of maintaining within the cars, by mechanical means, a continuous gentle current having a rotary and upward trend.

The lobsters are hatched by placing the old female lobsters carrying eggs, about ready to hatch, in boxes in wells on the pontoons; the horizontally revolving paddles contained in the wells are set in motion. As the eggs hatch one by one the larvæ are carried upward and off the bottom by the current just as they are in the ocean. The lobsters which hatch each day are placed in a separate rearing compartment likewise equipped with a horizontally revolving paddle. This is an important feature of the method as the young lobsters are cannibalistic, and, if those hatched on several different days are placed in the same car, the older individuals devour the younger ones when they moult. The larval lobsters are kept in the rearing car in the slowly moving current until they reach the fourth stage, after shedding their skins four times. The length of this larval period is dependent upon many factors, the chief being the temperature of the sea water and the food given them. In some cases the young lobsters are not planted until they reach the fifth stage of their development. The degree of success attained by this method is determined by the choice of the food, the attention given the equipment and the temperature of the ocean water. The advantages of this method over other methods, proposed previously, lies in its ability to keep the larval lobsters off the bottom from which they are unable to rise, and on which they fight each other until, from injury or suffocation, they all perish. Moreover the upward moving spiral current of water prevents the young lobsters from congregating anywhere and thus reduces the losses because of their cannibalistic proclivities.

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[3] Published by Moquin-Tandon and Soubeiran, J. L. in *Soc. impériale zoologique d'Acclimatation Bull. 2nd ser., t. 2* (1865), 535-545.

[4] *Bureau Fisheries Bull. 28* (1908), 219-240.

Chemical Composition and Nutritive Value of Lobsters.

Fresh Lobsters.

Comparatively few analyses have been made on whole lobsters or lobster meat, and those which have been carried out have, for the most part, only considered the proximate composition of the lobster. Morgulis[5] analyzed whole normal lobsters while carrying out some researches to determine the changes taking place in their composition during prolonged fasting. His results are given in Table 75. Atwater[6] has made an extensive study of the composition of materials commonly used for food in the United States. His analyses of fresh lobster and canned lobster are presented in Tables 76 and 77.

These data indicate that lobster meat contains a negligible amount of carbohydrates and only a small percentage of fat. The dry matter of lobster meat contains approximately 80 per cent of protein. Since in eating lobsters about 60 per cent of the animal is discarded, and approximately 80 per cent of the remainder is water, the total nutrient content of fresh lobster is small, being about 7 per cent. At present prices of lobsters, the cost of protein and fat purchased in the form of live lobsters is exceedingly high. The vitamine content of lobster meat has not been determined, but is probably relatively high.

TABLE 75

Average Composition of 5 Whole Lobsters

Constituent	Fresh Material Per Cent	Water-free Basis Per Cent
Dry matter	32.672	......
Water	67.328	......
Organic matter	21.010	64.305
Total inorganic matter	11.662	35.695
Non-volatile inorganic matter	8.955	27.409
Total glycogen	0.161	0.494
Ether extract	0.954	2.919
Alcohol extractives	1.831	5.605
Alcohol-extracted nitrogen	0.145	0.443
Per cent of nitrogen in alcohol extract	2.582	7.904
Water extractives	3.285	10.528
Water-extracted nitrogen	0.374	1.146
Per cent of nitrogen in water extract	3.558	10.891
Total nitrogen	2.168	6.636
Protein (non-extracted nitrogen × 6.25)	10.315	31.544
Undetermined	4.464	13.215

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[5] *J. Biol. Chem., 24* (1916), 137-146.

[6] *Agr. Exp. Sta. Bull., 28* (1906 rev.).

TABLE 76

Composition of Fresh Lobster

	Number of Analyses	Refuse	Water	Protein (N × 6.25)	Fat	Total Carbohydrates	Ash	Fuel Value per Pound
		Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Cals.
Edible portion:								
Minimum	5	....	68.6	11.6	1.5	...	1.6	345
Maximum	5	....	84.3	25.4	2.5	0.9	4.0	555
Average	5	....	79.2	16.4	1.8	.4	2.2	390
Whole Lobster:								
Minimum	5	44.0	18.0	4.4	.5	...	.6	115
Maximum	5	73.7	47.2	6.7	.9	.4	1.0	165
Average	5	61.7	30.7	5.9	.7	.2	.8	140

TABLE 77

Composition of Canned Lobster

	Number of Analyses	Water	Protein (N × 6.25)	Fat	Total Carbohydrates	Ash	Fuel Value Per Pound
		Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Cals.
Minimum	2	76.2	16.7	.5	.5	2.1	345
Maximum	2	79.4	19.5	1.7	.6	2.8	445
Average	2	77.8	18.1	1.1	.5	2.5	390

The Composition of the Shell of the Lobster.

The inorganic constituents of lobster shells consist chiefly of calcium carbonate and phosphate and magnesium carbonate. The shells of young lobsters contain a larger proportion of calcium carbonate and a smaller proportion of calcium phosphate than the shells of older lobsters. Clarke and Steiger[7] analyzed the inorganic constituents, claws and carapaces of a small, a medium and a large lobster. Their results are given in Table 78.

TABLE 78

The Inorganic Constituents of Lobster Shells

	Small		Medium		Large	
	Claw	Carapace	Claw	Carapace	Claw	Carapace
	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent
Iron, aluminum and silicon oxides	0.33	0.35	0.36	0.66	0.31	0.57
Magnesium carbonate ..	10.81	7.74	11.28	8.12	10.99	8.77
Calcium carbonate	72.41	78.98	55.46	70.58	56.89	65.14
Calcium sulphate	1.24	1.23	2.12	1.58	2.32	2.32
Calcium phosphate	15.21	11.70	30.78	19.06	29.49	23.20
	100.00	100.00	100.00	100.00	100.00	100.00

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[7] *Proc. Nat. Acad. Sci.*, *5* (1919), 6-8.

The New England Lobster Fishery.

Although the number and weight of lobsters caught annually in New England has decreased rapidly during the past fifty years, this fishery is still one of the most important fishing industries of that section of the country. The lobster catch in 1919 is given below by States:

	Weight	Value
Maine	5,545,884 lbs.	$1,411,548
New Hampshire	298,012	73,203
Massachusetts	2,387,636	516,393
Rhode Island	1,694,327	360,679
Connecticut	740,848	189,157
Total	10,666,707	$2,550,980

In Maine the lobster fishery is by far the most important fishing industry of the state, the value of the lobsters caught being about 36 per cent of that of all fishery products landed. The demand for live lobsters has forced the retail price of this crustacean to such a high point that it must be considered a luxury by all but the rich. This rapid rise in price has kept the value of the lobster fishery up in spite of the rapidly decreasing annual catch.

The figures given above indicate that over half of the New England lobsters are caught in Maine, and that Massachusetts and Rhode Island are also important lobster producing states.

Some lobsters are also caught in New York, New Jersey and Delaware but this industry is comparatively unimportant.

Methods of Fishing.

Pots.—Lobsters are captured in traps called pots or creels, which vary greatly in shape and dimensions in different sections of the country but which operate on the same principle. In general, they consist of oblong lath boxes in which bait is placed. These pots have one or more funnel shaped openings, usually inclined obliquely upward, through which the lobsters pass in their search for food. Once inside the trap, relatively few are able to escape by finding the hole at the small upper end of the net funnel. Some pots have a funnel in each end, others have an inner compartment reached only through a second funnel.

The type commonly used in Maine has a flat bottom and is semicylindrical in form, being about 4 feet in length, 2 feet in width and 18 inches in height. These traps are constructed of ordinary house laths, of spruce or pine, nailed lengthwise to a hard wood framework. Each end consists of a funnel shaped coarse meshed net. The larger end of this net has the same diameter as the framework of the pot; the smaller and inner end is about 6 inches in diameter and is held open by means of a wire ring or wooden hoop. These funnel-shaped nets are constructed so that when they are in place they lead obliquely upward into the pot. The inner ends are held in position by one or two cords extending to the center frame. The funnels are about a foot deep and therefore extend about half way to the center of the pot. The captured lobsters are removed through the top of the pot by means of a door consisting of three or four laths on a frame attached to leather hinges fastened by wooden buttons.

In Rhode Island many oblong slat pots are used. They vary in length from 2 feet 10 inches to 4 feet and are from 17 to 24 inches wide and from 12 to 20 inches high. Each pot has two funnels about 10 or 12 inches deep, made of two strand manila twine with 1 inch mesh. The outer funnel, like that of the creel described above, is inclined at an angle of 65 degrees with the bottom of the pot. The smaller opening of the inner funnel terminates in a collapsible hoop of twine which the lobster pushes open as he enters the inner compartment, and which collapses behind him and shuts off his retreat. The door is usually constructed on the side in this type of pot. The bait is fastened upon a peg or spear which is fixed upright in the inner compartment.

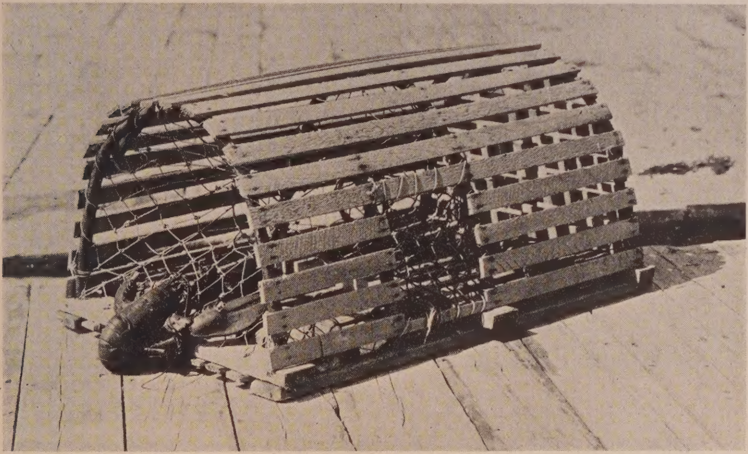

FIG. 210.—A lobster pot.

Many other types of pots are in common usage but space will not permit their description.

In order to keep the pots on the bottom, they are weighted down by bricks or stones which are fastened to the bottom on the inside.

Bait.—Almost any kind of fresh, salted, or stale fish is used as lobster bait, the choice depending upon the custom in the particular community and on the kind of bait obtainable. Where cod, cusk, haddock, and halibut heads are obtainable in quantity these are often used. Small, lightly salted, partly decayed herring are a favorite bait in certain sections of Maine. Some lobstermen prefer partly decayed bait; they maintain that the odor attracts the lobsters; others prefer fresh bait. Other fish commonly used for bait are the following: menhaden, cod, flounder, sculpin, cunner, sea robin, skate and scup.

Fishing.—The pots are either set on single warps or on trawls having from 3 to 60 traps attached. In the early days of the industry, all pots were set singly, but the lobstermen discovered that, if the pots were attached to trawls, one man could fish alone. When the pots are set singly one man is usually required to handle the boat while the other hoists the traps, removes the lobsters and renews the bait. One end of the line, by which the pot is hauled up and lowered, is fastened to the framework of the creel, the other is attached to a buoy which usually consists of a piece of cedar or spruce painted a distinctive color so that each fisherman may easily recognize his own traps. Often two buoys are used, one being placed about the middle of the line and the other at its upper end; this prevents the line from fouling on the rocky bottom.

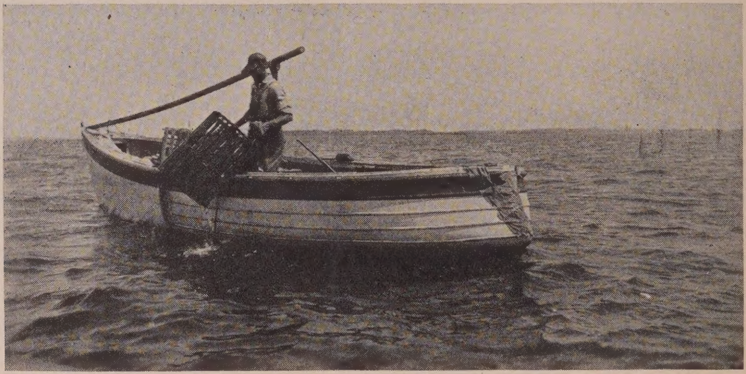

FIG. 211.—Fisherman pulling a lobster trap.

Preservation of Live Lobsters.

Lobsters are marketed either alive, boiled or canned. Since boiled lobsters spoil quickly and are therefore often of questionable quality, the greater portion of the lobsters are marketed alive. Each lobsterman has a live-car in which he keeps his catch until they are sold. These cars are usually oblong, rectangular boxes, with open seams or numerous small holes to permit the free circulation of the sea water. Their average size is about 6 feet long, 4 feet wide and 2 feet deep. The door through which the lobsters are introduced and removed is on the top. Dealer's cars are quite similar to those used by the fishermen except that they are much larger; a common size is 30 feet long, 12 feet wide and 3 feet deep. Such a live-car will hold from 2,000 to 3,000 lobsters depending upon their size. Dealer's cars are usually divided into several transverse compartments; each of which is provided with two large doors. The lobsters are removed from the cars by means of dip nets attached to long wooden handles. When in use the live-cars are usually moored in a convenient spot close to the shore.

The depth at which the pots are placed depends upon the season, the shore, and the nature of the bottom. In winter the lobsters retire to deeper water, usually to the open sea and are more scattered than in summer when they are found in shallower water often in bays and harbors. Because of this, the pots are set further apart in winter, and in deeper water further from the shore. In warm weather, the traps are set in water from 2 to 10 fathoms in depth, but in cold weather, commonly at from 10 to 25 fathoms. Formerly very little fishing was carried

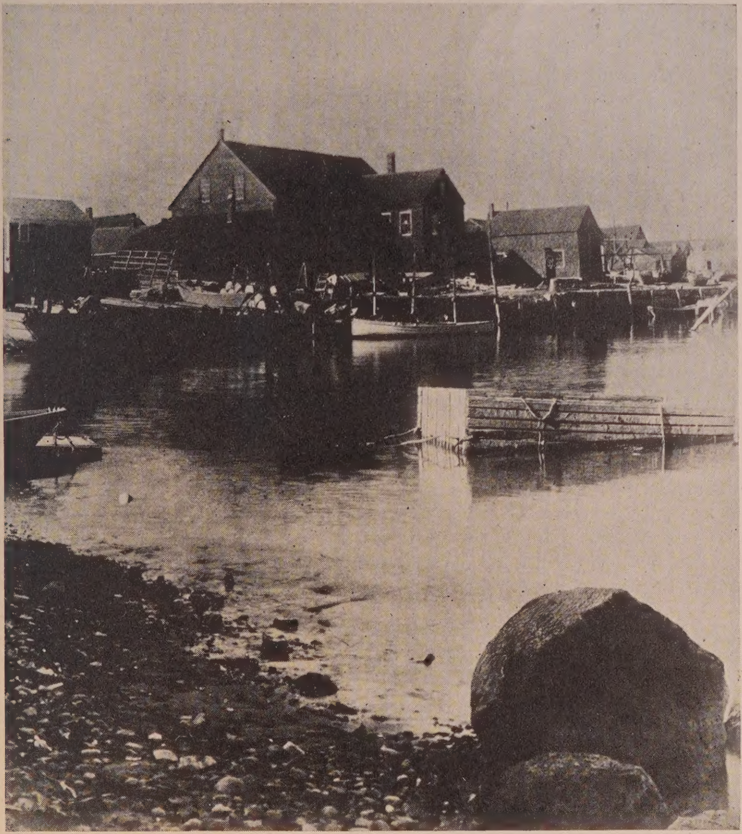

Photo by Spooner.

Fig. 212.—Lobster live-car moored close to shore in quaint Rockport, Massachusetts.

out in winter but now many lobstermen continue their operations throughout the year.

Where lobsters are plentiful, the traps are hauled twice daily, but because of their increasing scarcity in New England, it seldom pays the lobstermen to haul their traps more than once each day. Many fishermen set as many as 100 pots. The average number of traps set by the fishermen has increased in recent years as the number of lobsters caught per trap has decreased; this increase in the number of pots used was necessary in order to maintain the number of lobsters caught at the former level.

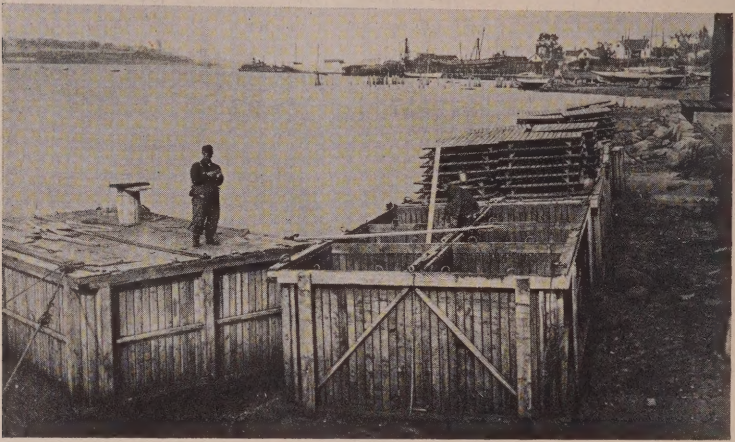

Fig. 213.—Dealer's live-cars for lobsters.

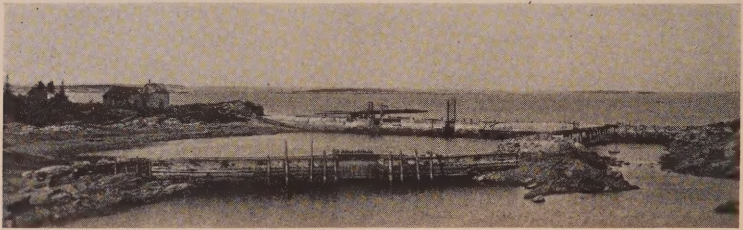

Fig. 214.—View of pound at Stave Island, Maine. The pound in the foreground is used in summer for keeping "shedders."

Transportation of Live Lobsters.

On Vessels.—A large proportion of the Maine lobsters are caught along shores which have no direct rail connections, and they must therefore be transported by water either to a market or to a railroad station where they are shipped on ice to distant markets. Lobsters which are shipped in smacks are carried in wells, usually between the pilot-house and the engine-house. Small holes in the bottom of the wells keep them filled with fresh sea water. These well-smacks have regular routes on which they visit various fishermen and purchase the lobsters which they are holding in their live-cars, and transport them to the city markets.

Shipments by Rail.—Lobsters are shipped by express by packing them in barrels with ice. Second-hand sugar or flour barrels are ordinarily used as containers. A cake of ice weighing about 100 pounds is split lengthwise into three pieces. One of these pieces is placed upright in the center of a barrel and the lobsters are packed snugly all about it. When the barrel is nearly full, the lobsters are covered with seaweed or paper and the rest of the space is filled with cracked ice. A piece of sacking is then placed over the top and is fastened under the upper hoop of the barrel.

Boiling.

Live lobsters are preferred in nearly all markets, and consequently comparatively few lobsters are boiled before marketing. In many districts, retail dealers boil live lobsters for their patrons after their purchase.

Boiled live lobsters will keep for a week if they are packed in ice. Much boiled lobster meat is picked from the shell and sold for the preparation of salads and for other purposes.

The form and size of the boilers used for cooking lobsters vary widely; the large dealers use rectangular tanks or vats partially filled with water into which steam is passed. The live lobsters are placed in an iron framework basket which is lowered into the tank by means of a small derrick. Small dealers and fishermen use boilers varying in size from an ordinary wash-boiler to a smaller form of the tank used by the larger dealers.

A small amount of salt is usually added to the water used for boiling the lobsters. The lobsters are usually boiled for a half hour or until the proper red color indicates that they are sufficiently cooked.

The Canadian and Newfoundland Lobster Fishery.

The Live Lobster Industry.

The methods employed by lobstermen in Canada and Newfoundland very closely resemble those used in the United States. However, the scale of the business is very much greater in Canada than anywhere else in the world. In 1920, Canada alone produced 37,685,500 pounds of lobsters valued at $4,249,480. If the average weight of a lobster is taken as one pound the number caught was over 37,000,000 which is more than double the production of the remainder of the world. In Nova Scotia alone, there are about 20,000 men employed in lobster fishing during the season.

The Canadian and Newfoundland lobstermen, for the most part, use the same style of pots as those commonly employed in the Maine and Massachusetts fishery. The style of traps has changed from those with slats two inches or more apart to traps which retain nearly all the small lobsters which enter. The dimensions and shape of the pots vary in different localities depending upon the custom in the vicinity and the ideas of the individual lobsterman; but, as in Maine, the semicylindrical trap with an entrance funnel at either end is most popular.

As in New England, the fishermen set their pots in relatively deep water in cold weather, but, with the arrival of spring, they bring them nearer the shore. Since the year 1874, closed seasons have been established in the different Canadian Provinces. At present the length and time of this closed season varies in various sections of the coast. The open season has been greatly restricted in all the provinces and in some cases has been limited to six weeks. The minimum legal length also varies in the different provinces from 8 to 10.5 inches; but this law is not strictly enforced. The taking of berried lobsters has been forbidden in Canada since 1873.

The long closed season makes the Canadian lobster fishery a seasonal industry. Thus all the lobstermen engage in other occupations for the greater part of the year; a few of them are farmers, but the greater majority fish during the closed season.

The live lobsters are usually collected from the lobster fishermen in well-smacks by the canners or wholesale dealers. The wholesale dealers transport the lobsters either to the markets in the well-smacks or to a shipping point where they pack them in barrels with ice and ship them to the markets.

A large portion of the lobsters marketed alive are exported to the United States. Portland, Boston and New York are the most important lobster importing markets in the United States.

The Canning of Lobsters.

No lobsters have been canned in the United States since 1895, because the Maine law restricting the sale of lobsters less than 10.5 inches in length has made it impossible for the packers to obtain large quantities of cheap lobsters. In Canada and Newfoundland, laws restricting the use of short lobsters have been made but have not been strictly enforced, and consequently the canners have been enabled to operate profitably. The canning industry is conducted on a large scale in the maritime provinces. In 1920, 160,000 cases of lobster were packed, whereas in 1919 only 126,640 cases were canned.

The first step in the canning of lobsters is boiling. The live lobsters are usually placed in an iron framework basket which is lowered by means of a small derrick into rapidly boiling water. The boilers in common use are rectangular wooden tanks lined with zinc and equipped with a cover. These tanks are heated by steam which is passed into the water in the boiler through perforated pipes in the bottom. About 3 per cent of salt is usually added to the water used in boiling the lobsters.

After boiling for 20 to 30 minutes, the lobsters are cooled in a cold salt solution. When the lobsters are cool enough to handle the claws and tail are broken off. The body shell is opened, the stomach, liver and corral removed, and the body taken out of the shell. The claws are cracked and the meat removed whole, if possible. The "arms" are split longitudinally and the meat removed with a fork. The tails are split and the intestine is pulled out.

The meat is usually packed in No. 1 cans lined with parchment paper, which prevents the meat from coming in direct contact with the tin and thus prevents discoloration of the lobster meat by the tin. In filling the cans the tails are usually placed in the bottom, and the arm-meat and the claws on top. Salt is always added, either dry or as brine. Occasionally the lobster is flavored with pepper, bay leaves, and cloves.

The early practice followed in canning lobsters was to heat the sealed cans for an hour and a half in a huge vat of boiling water. The hot cans were punctured and again sealed and the cans again heated in the vat of boiling water for one hour.

The modern procedure is to exhaust the topped cans in a steam box for about 10 minutes, after which the cans are vented and sealed. The sealed cans are then heated in a retort at a temperature of 250° F. for one hour. The cans are cooled in cold water, 48 one-pound cans or 96 half-pound cans are packed in a case.

American Spiny Lobster Fishery.

The sea crawfish or spiny lobster (*Panulirus argus*) is caught in considerable quantities on the coasts of southern Florida and southern California. On the Atlantic Coast, its northern limit is said to be Beaufort, North Carolina, and its southern limit, Rio de Janeiro, Brazil. The present annual catch in Florida has been estimated to be 300,000 pounds valued at $25,000. The California catch is of approximately the same size; in 1920, 247,156 pounds were sold. Nearly a million pounds of these lobsters are imported from Mexico each year.

In Florida, some sea crawfish are caught all the year round, but in California the season is from October to February inclusive. The best fishing grounds in Florida are along the southern shores of the reefs and keys extending from Boca Grande Key on the west to Sugar Loaf Keys on the east.

About half of the catch in Florida is taken in bully nets, the remainder is caught with traps, grains, hoop nets, seines, and hooks. The "bully" is a small hoop net 15 to 18 inches in diameter, 2 feet or more in depth and with mesh of 1¼ inch bar measure. The bully net is used chiefly in water of 10 feet or less depth where the fisherman can see them on the bottom. The fishing is better at night than during daylight as during the day many of them conceal themselves under rocks, sponges, and corals. At night, a lamp similar to a street lamp is fastened to the bow of the boat, thus enabling the fisherman to examine the bottom. Traps constructed of galvanized iron wire are commonly used for catching the spiny lobsters in deep water. This is the chief source of supply during the summer months when the lobsters retire to deeper water.

Crawford and De Smidt [8] have described the marketing of the Florida crawfish as follows:

> The spiny lobsters are taken to the local markets alive, having been kept in the wells where there was a free circulation of water. . . .

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[8] *Bureau Fisheries Bull. 38* (1921-2), 279-310; also Doc. 925 (1922).

At the market the catch is sorted, counted, and transferred to floating cars or inclosures where it is kept until ready for shipment. Spiny lobsters which have died and those in a dying condition are sold as bait to the hook-and-line fishermen. The market value varies from $0.75 to $2 per dozen according to season and demand and size. The average price obtained by the fishermen is $1 per dozen. The dealers sell by the pound. The average spiny lobster weighs about 1½ pounds. . . .

During cool weather spiny lobsters shipped to points in southern Florida are simply placed in wet sacks, and under such conditions they will live 4 or 5 hours. If properly packed, they will live from 2 to 3 days. During the winter and spring months many spiny lobsters are shipped as far north as Philadelphia, New York and Boston. They are packed in barrels containing alternate layers of ice and shellfish.

The method of packing is the same as that employed in preparing fish for shipment, except that a layer of sponge clippings or seaweed separates the shellfish from the ice. The average barrel will hold from 10 to 12 dozen spiny lobsters.

The European Lobster Fisheries.

The Development of the Fishery.

Although lobsters have been known to people of Northern Europe since early times, they were seldom eaten by the fishermen until the modern era. Since about the year 1800, the lobster industry has become an important fishery in Norway and the British Isles. One of the earliest methods of taking lobsters was by hooking them under the body with a hook fastened on a long pole. In the early days of the industry, tongs were commonly used in shoal water by fishermen in small boats. These methods of fishing are applicable only in shallow water where lobsters are plentiful, and they usually injure the lobsters so that they cannot be transported any great distance to market. The first important improvement in methods of lobstering was the use of the "plumper." This trap consisted of an iron ring to which a net bag was fastened so as to form a deep bag below in which the bait was placed near the bottom. Such traps had to be carefully watched and pulled very often as the lobsters could escape easily. At present, cylindrical traps or creels are largely used which operate on the same principle as those used in New England and Canada, differing chiefly in shape. They are commonly small cylinders, made of a wooden hoop frame covered with netting, with entrance funnels in both ends. They are usually anchored by means of flat stones tied to the bottom.

Varieties of Lobsters Caught in European Waters.

The American lobster (*Homarus americanus*) is not found on the coast of Europe. The true European lobster is *Homarus gammarus*, which resembles the American lobster very closely, but is distinguished by the narrower spine on its forehead, and by having teeth only on its upper margin. The langouste (*Palinurus vulgaris*) is commonly found on the coast of France and Spain and in the waters of the Mediterranean; this crustacean is sometimes called crawfish of the sea, thorny lobster, spiny lobster, rock lobster, and red crab; it is not a true lobster, though it is often classed with lobsters. In Great Britain, it is commonly called the thorny lobster and has been found in various localities along all the coasts of the British Isles but it is common only on the southwest coast of England. The langouste is much esteemed as an article of food, although considered of inferior flavor to the lobster. A closely related species is found on the American coast from California to Mexico and along the Gulf coast of Florida.

The Present Extent of the European Fishery.

While the lobster fishery is an important industry in Norway and the British Isles, it is very small when compared to the American fishery. The latest available figures regarding the British lobster industry are given in Table 79.

TABLE 79

LOBSTERS TAKEN IN EUROPE

England and Wales (1920)	715,338	lobsters
Scotland (1920)	765,850	“
Ireland (1920)	190,099	“
Norway (1917)	1,924,120	“

Lobsters are very high priced in Europe, particularly in France. Many attempts have been made to export live lobsters from the United States to England, but, because of large losses en route, this has never proved financially successful. Large numbers of Scandinavian lobsters are sold in England. Many lobsters caught in the British Isles are exported to France.

The high price of lobsters in Europe has made canning unprofitable; consequently practically all that are taken are sold alive.

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Chapter 32.

Marine Turtles and Terrapins

Location and Importance of Industry.

The three most important species of true marine turtles are the green turtle, the hawk'sbill turtle and the loggerhead turtle. The luth or leathery turtle is also a true marine turtle and is found on the coasts of Florida and Brazil but it is of no commercial importance. The diamond-back terrapin, which is such a valuable commercial article, is not a marine turtle in the correct sense of the word but is a water tortoise and resembles the land tortoises very closely, although it lives chiefly in saline river estuaries and salt marshes.

Of the three important species of marine turtles, the green turtle is the only one commonly eaten. Its flesh is prized, especially for the making of turtle soup, by the large hotels of the North and as a source of meat supply to the inhabitants of the West Indies and Central America. The hawk'sbill turtle is the source of the tortoise shell of commerce.

The marine turtles inhabit the tropical and semi-tropical seas at all seasons and in summer a few are found in temperate seas. In the United States, marine turtles are found chiefly in the Gulf of Mexico and particularly along the coast of Florida although small numbers are found as far north as New York. The statistics presented in Table 80 concerning the catch of turtles and terrapins in the United States in the year 1918 show that the industry is only of slight importance. Cuba, Yucatan, Mexico, Costa Rica, and Nicaragua possess important fisheries, and in Brazil many turtles are caught near the mouth of the Amazon River.

The Green Turtle Fishery.

The green turtle, *Chelonia mydes,* is the only true marine turtle that is commonly eaten. Its fat is a greenish color and this characteristic has given it its popular name. The shields of the carapace are smooth and are brown, mottled with yellow and fringed with white or yellow. Although the shell is attractively colored it is of no commercial value. This turtle attains a length of 3 to 4 feet and a weight of 300 to 500 pounds. It is omnivorous but feeds largely on marine vegetation. This turtle lives almost entirely in the sea and never comes ashore except on brief trips to lay its eggs. The plastron is not rigidly constructed and will not support the weight of the turtle when it is on land; because of this the turtles soon die if they are not turned on their backs when out of the water.

The chief green turtle fishery of the United States is in the vicinity of Key West, Florida. At present, chiefly because of overfishing, the

TABLE 80

STATISTICS FOR THE YEAR 1918 CONCERNING TURTLE AND TERRAPIN FISHERIES OF THE UNITED STATES

	Pounds	Value
Florida:		
Turtles	72,220	$4,831
Terrapins	2,475	206
Georgia:		
Turtles	11,250	100
Terrapins	2,112	454
South Carolina:		
Terrapins	1,275	545
North Carolina:		
Turtles	8,400	77
Terrapins	210	92
Alabama:		
Terrapins	2,938	1,104
Mississippi:		
Turtles	337	20
Terrapins	5,600	3,900
Louisiana:		
Turtles	4,360	218
Terrapins	23,406	7,578
Texas:		
Turtles	6,671	447
Terrapins	2,850	990

catch of green turtles on the Florida coast is very small and many more are caught in the West Indies and off the eastern Nicaragua and Costa Rica coast. Practically all the green turtles shipped into the United States are first landed at Key West.

The catching of sea turtles is largely a vessel fishery, schooners or sloops being employed. The most popular form of gear is the gill net. The fishing season is from March to September inclusive.

The Key West Turtle Industry.*

Shipments of live turtles are made to New York on the coastwise steamships and usually consigned to Fulton Market whence they are distributed to other centers. New York imports but part of its green turtle supply from Key West, as many are brought by steamship directly from the West Indies and Central America. They vary slightly in value according to size. The New York wholesale market prices of December 28, 1918 were as follows: turtle, green, under 100 lbs., 18 cts.; 100 lbs. to 150 lbs., 17 cts.; 150 to 200 lbs., 16 cts.; over 200 lbs., 13½ cts.

One dealer and one cannery handle all of the green turtles brought into Key West. The turtles are landed by schooners known as "turtle boats," and are placed in pens made of closely spaced palmetto logs in which they will live for a long while with practically no mortality. In an enclosure of about 40 by 70 feet, divided into several smaller enclosures, as many as 500 or more large turtles have been kept at one time.

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* From Schroeder, W. C., "Commercial Fisheries of Key West, Florida." To be published in Bureau Fisheries Rept., 1923.

When a turtle is to be taken from the pen a rope noose is dangled in the water until it catches the flipper of a turtle as it comes up to breathe. The rope is at once hauled taut and the animal is hoisted to the dock, the precaution being taken to render it helpless by turning it on its back before the noose is cast loose. Turtles are shipped lying on the backs, and to prevent their righting themselves all four limbs are bound together by a rope yarn passed through a hole punched in each flipper. This method of keeping them overturned has been branded as cruel, but it appears to be a necessity, although the piercing of the flippers is not absolutely essential.

Turtles to be used for canning are slaughtered on the dock each day at 3:30 P.M., when an inspector is present to see that the butchering is done in a correct and sanitary manner. None is killed until the desired number has been removed from the pens and placed about one foot apart on the dock. One person rapidly strikes the head and four flippers of each turtle with a sharp axe, nearly severing each. Two men with sharp knives then dexterously cut away the plastron and remove the entrails, sea water being thrown on the carcasses during the operation to wash away the blood and slime. The flesh is then cut from the carapace, thrown into a barrel of sea water where it is washed, and taken to the cannery where it is hung up over night before being used. The following morning a small portion of the meat is sold to the public at about 25 cents a pound and the remainder is canned as turtle soup and turtle meat.

One prominent chef has stated that the carapace is one of the best parts of the green turtle for soup, but the Key West cannery disposes of this, the plastron, and the entrails by dumping them into the sea some distance from shore.

During May, June and July the females contain both mature and immature eggs, and are greatly enhanced in value because of the demand for the eggs. The white or mature eggs sell for 25 cents per dozen, while the yellow or immature eggs command 50 cents per pound and are considered a great delicacy. A female is said to carry from 6 to 30 pounds of eggs according to its size and condition. The white eggs are about the size of a golf ball and the parchment-like shells do not break if dropped from a considerable height.

The Costa Rican Fishery.

On the Costa Rican and Nicaraguan coasts the turtles are captured principally when they come ashore to deposit their eggs. The turtles usually come ashore during the night so the "turtling" is done before daybreak by men armed merely with lanterns to locate the turtles which are then simply turned over on their backs, thus rendering them helpless. Meily,[1] the American Consul at Port Limon, has described the collection and marketing of the turtles:

> When the beach has been covered, and all the turtles secured, the captives are ingeniously made to transport themselves to the turtle launch or schooner which cruises along the coast at a safe distance off-shore; this is accomplished by fastening to one of the turtle's flippers or front legs, a piece of strong line about ten

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[1] Meily, J. J., *Consular Rept.* dated April 16, 1923.

feet long, to the other end of which a float or buoy of balsa (a very light cork-like native wood) has been fastened. The turtles are then turned over on their bellies and allowed to scramble off into the water; they of course promptly head for the open sea but being hampered by the wooden float make slow progress; as soon as they have cleared the surf the floats are picked up by the turtle boat, the line hauled in and the turtle at the other end is hoisted aboard by means of block and tackle; the turtles are then brought to Port Limon where they are placed into crawls or pounds and kept until marketed.

. . . .

The average green turtle catch is about 750 per year and about the same number of hawk'sbill turtles are taken. Green turtles are shipped to New York and Key West (the principal American markets), Colon, Panama, Kingston, Jamaica; the Caribbean islands of San Andres and Providence (belonging to Colombia) are also important markets; the average weight of female green turtles is about 200 pounds (but they are taken at all weights from 100 to 500 pounds) and they sell for about $10.00 each; there is little demand for males and practically all the turtles shipped are females. Turtle meat is always to be obtained in the local Port Limon market; the meat is known as "calipash" which is the fatty greenish flesh from the belly of the reptile; the meat is also dried, and more rarely, smoked.

The Hawk'sbill Turtle Fishery.

The chief source of tortoise shell is the shields of the carapace of the hawk'sbill turtle, *Chelonia imbricata*. This turtle is the smallest marine turtle and seldom reaches a length of more than 30 inches although shells thirty-four inches in length have been found. It may easily be distinguished from other marine turtles by the arrangement of the shields of the carapace which coarsely overlap like shingles. These shields are transparent and are beautifully mottled black or brown and yellow. The shields of the head and limbs are brown or black tinged with pale yellow about their margins.

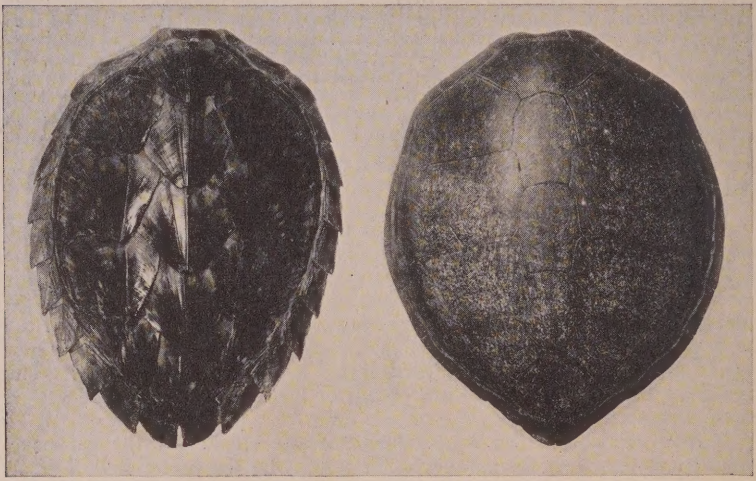
Figure 215 shows the arrangement of the shields of the carapace. Thirteen plates cover the carapace, five occupying the center and four on each side. These overlap each other to nearly ⅓ of their whole size. The plates on the larger turtles measure approximately 8 by 13 inches and weigh about 9 ounces. The carapace has also 12 pairs of marginal shields which form a strongly serrated sharp edge on the posterior half of the shell. The small marginal shields and the plates of the plastron are inferior in value to the larger shields.

These turtles are found in nearly all parts of the tropical and semi-tropical seas. The best grades of tortoise shell are obtained from the Eastern Archipelago, particularly from the east coast of Celebes to New Guiana. Large quantities are also taken in Brazil and in the West Indian Islands.

The Manufacture of Tortoise Shell.

The shields are removed from the shell of the live or freshly killed turtle by heat; either by immersion in boiling water or by heating it over a hot fire. Tortoise shell is worked in the same manner as horn but, since it is more costly, greater care must be taken in its treatment. When the plates are first removed, they are keeled, curved and irregular in form. They are first flattened by heat pressure. High heat tends to darken the shell, therefore the shell must be treated at as low a heat as possible. Tortoise shell can be welded together when hot by pressing pieces together in a vise. The heat softens and partially liquefies a superficial film of the shells which may then be united by pressure. The welds may usually be noted by a very careful examination, but this is immaterial for many of the purposes for which tortoise shell is required.

Tortoise shell has been highly prized for ornamental purposes since early times. It was one of the treasures of the Far East brought to Rome through Egypt. At present tortoise shell is used in the manufacture of valuable inlaid work, for toilet articles such as combs and brushes, for knife handles and various other ornaments.



Courtesy Philippine Bureau of Science.

FIG. 215.—Left—Shell of Hawk'sbill turtle, the source of the tortoise shell of commerce.
Right—Shell of the green turtle.

The horny shields of the carapace of various other turtles are sometimes used as tortoise shell but they are poor imitations as they are either opaque or soft and leathery.

The flesh of the hawk'sbill turtle is eaten to a slight extent but it is not highly regarded.

The Loggerhead Turtle.

The loggerhead turtle, *Thalassochelys caretta,* is the common marine turtle found along the Atlantic Coast from New York southward and is abundant from North Carolina to Florida. It is of little economic value; the eggs are commonly eaten but the meat is only occasionally used for food. The shields of the carapace are opaque and therefore of little value.

The larger loggerhead turtles have a shell about 3.5 feet in length which is uniformly brown above and yellowish below. This turtle has five pairs of costal shields and usually 23 marginal shields. The head is much larger and coarser than that of the green turtle. The loggerhead turtle is a carnivorous reptile living chiefly on fish.

Along the South Atlantic Coast and the West coast of Florida this turtle comes ashore at night during the early summer to lay its eggs. From 60 to 160 eggs are laid in the "nest" at one time. These eggs which are about half the size of hen's eggs, are sold locally, but are rarely shipped. The eggs are found by probing the turtle tracks in the sand until a nest is discovered. The egg shells are only slightly calcareous and are therefore soft. Since the contents do not completely fill the shells, there is always a dent in the egg.

Loggerhead turtle meat is eaten by the fishermen along the coasts where it is found but it is seldom shipped.

Other Marine Turtles.

The Kemp's Gulf turtle, *Thalassochelys colpochelys kempii,* is found in the Gulf of Mexico and on the Atlantic Coast as far north as North Carolina. Although it is eaten along the coast where it is found, it is of no commercial value. By many persons the meat is considered superior to that of the loggerhead and nearly as good as that of the green turtle.

The luth or leathery turtle is found along the coasts of Florida and Brazil. This turtle derives its name from the absence of the horny shields which are found on other marine turtles and from the leather-like skin which covers the bony carapace. The leathery turtle attains great size; specimens have been found which were about 8 feet long and weighed over 1600 pounds. This turtle has no commercial value as its flesh is unfit for food.

The Diamond-Back Terrapin.

The diamond-back terrapin is without doubt the most valuable marine delicacy marketed in the United States. Six-inch terrapins often sell as high as $60 a dozen and larger ones command higher prices. They possess highly esteemed edible qualities and are very scarce.

Diamond-back terrapins are found chiefly in salt or brackish marshes near the coast and at one time were abundant. These terrapins belong to the genus *Malaclemys* of which Hay[2] gives four species and one subspecies as follows: The Carolina terrapin, *Malaclemys centrata,* with a range extending from central North Carolina to Florida; the Chesapeake terrapin (*M. centrata concentrica*), which occurs in Chesapeake Bay southward to the North Carolina sounds and northward to Buzzard's Bay; the Florida terrapin (*M. macrospilota*), along the Gulf coast of Florida; the Louisiana terrapin (*M. pileata*), which inhabits the coast east and west of the mouth of the Mississippi River; and the Texas terrapin (*M. littoralis*), which occurs along the coast of Texas and southward.

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[2] *Bureau Fisheries, Ec. Cir., 5* (Rev.), (1917).

Although terrapins were once plentiful in the salt marshes along the Atlantic Coast, relatively few are found in that locality at present. The fishery is centered in Louisiana and Mississippi, yet in 1918, those two states produced terrapin value at only $11,478. The production statistics for 1918 of the various states are given in Table 80.

The Decline of the Terrapin Fishery.

The commercial diamond-back terrapin fishery became of importance about the year 1845. In 1880, 406,308 pounds of terrapin valued at $44,118 were marketed. At that time, the industry was centered in North Carolina and Virginia; these two states produced nearly 70 per cent of all the terrapins produced on the Atlantic Coast. The Mississippi and Louisiana fishery was then of slight importance. Overfishing has rapidly exhausted the Chesapeake and North Carolina terrapin fisheries, and, because of the scarcity of these terrapins, the southern terrapins have come into demand. At present, practically all of the terrapins are taken in the Gulf States.

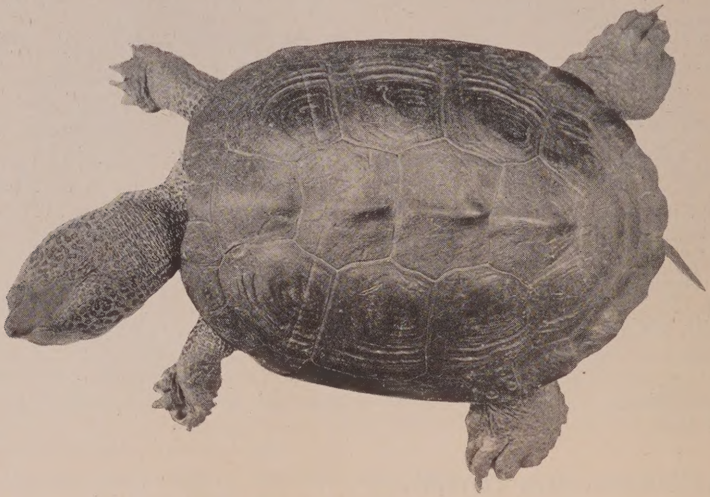
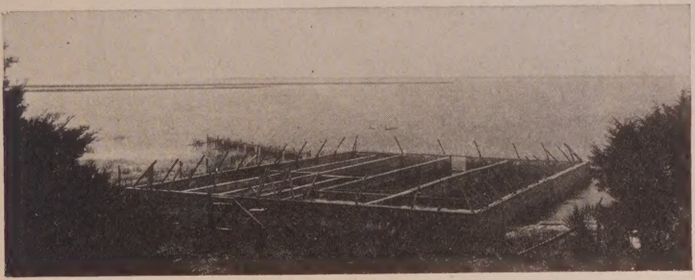


FIG. 216.—Adult diamond-back terrapin.

Habits and Propagation of Terrapins.

Because of the threatened extinction of this valuable aquatic animal, the U. S. Bureau of Fisheries and the North Carolina Geologic and Economic Survey have made extensive studies concerning the habits and life history of this terrapin and have carried out comprehensive researches extending over many years on methods of propagation. A large part of these studies have been carried out at the U. S. Bureau of Fisheries' Biological and Fish Cultural Station at Beaufort, North Carolina.

At low tide, terrapins are usually found nearly or entirely buried in the mud or hidden under drift, but are occasionally seen crawling about. At high tide, they swim about over the marshes in search of crabs, snails and other gastropods, and marine worms on which they feed. Terrapins grow rather slowly, requiring about six years to reach maturity, the female at that time being 5½ or 6 inches long and the male about 4 or 4½ inches in length. The terrapins lay their eggs in the spring or early summer at a depth of 3 to 8 inches on sandy elevations in the marshes usually above the high tide mark. The "nests" contain on the average about a dozen each, varying from 2 to 12 eggs. The eggs hatch about three months after they are laid; the newly hatched terrapins seldom eat any food before they hibernate, but live during the winter on the masses of egg yolk in their stomachs.



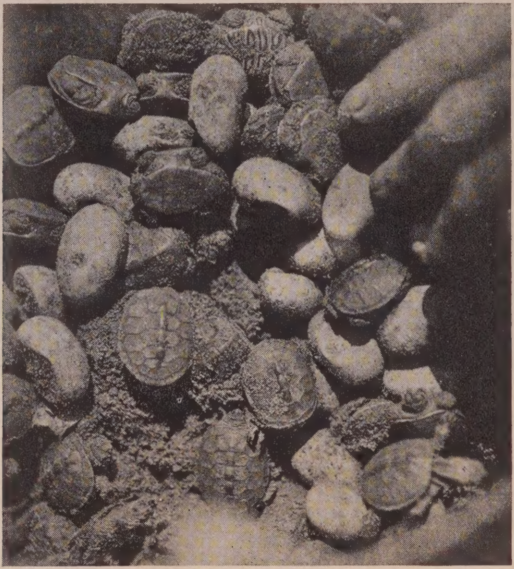
Courtesy Bureau of Fisheries.

FIG. 217.—A pound where the diamond-back terrapin is propagated.

Many individuals have attempted to raise terrapins but without much success. It required a thorough study of the problem for the Bureau of Fisheries' investigators to discover the cause of the failures. These investigators succeeded by studying the terrapins in their native abode and then keeping the terrapins under conditions similar to those to which they were accustomed.

The terrapins are impounded on a well-protected gently sloping shore of sand or clayey sand, so situated that, at high tide, every part of the inclosure, with the exception of the egg beds, is covered with water, and at low tide water still covers half the area. The enclosed area should allow at least 10 square feet for each impounded adult terrapin. The walls of the pen must be high enough and strong enough to overtop the highest tides by at least three feet and to resist any waves which may strike them. The pen is divided into two parts—a large area for the adult terrapins and a much smaller one for the young. The enclosure for the young should be partly dry at low tide but should always contain some water. The young terrapins are good climbers until they reach two or three years of age; therefore their pen must be constructed with great care. The adult terrapins are fed on fish and crabs; the young terrapins are usually fed on fish or oysters during their first winter. The terrapins can thrive without fresh water but usually their pens are supplied with fresh water in a shallow drinking trough.

A bed of sand above the highest tides is provided as a nesting place. After the close of the laying season, the adult terrapins are kept off the egg bed. Usually about 90 per cent of the eggs hatch. As the eggs hatch, the young terrapins are collected and placed in the shade in tubs or tanks containing a little fresh or salt water. Feeding with fish, crab meat or oysters is commenced as soon as the young terrapins are placed in the tanks; at first only a few eat but after three or four days most of them begin to feed. If the young terrapins are to be allowed to hibernate, suitable quarters should be prepared for them as soon as cool weather comes in the fall. A large box containing layers of sand and eelgrass when sunk in the sand in a well drained spot answers well for the purpose. The Bureau of Fisheries has found that it pays to keep the newly hatched terrapins in a warm house during their first winter and thus prevent their hibernation. By this means, the terrapins are fed through the winter and thus prevent loss because of hibernation. The winter house is constructed like a greenhouse, with the south slope of the roof of glass, and is heated by a coal stove which maintains the temperature between 80 and 85° F. The tanks are placed on trestles in this house and the terrapins fed as before.



Courtesy Bureau of Fisheries.

Fig. 218.—Digging young diamond-back terrapin from the nest.

The young terrapins should be kept separate from the older ones until they are three years old. The older terrapins do not harm the younger ones intentionally but in a crowded pen they kill their offspring by trampling over them and by depriving them of food.

The Bureau of Fisheries has been very successful in propagating terrapins at the Beaufort Station by the method outlined above. The experiments have dealt with but two species of diamond-back terrapin, namely the Carolina terrapin and the Texas terrapin, but it is probable that the other three species may be successfully propagated by similar methods.

Methods of Fishing.

Because of the scarcity of terrapins, the fishery is of little importance commercially and only a relatively few fishermen engage in it as a part time occupation. The drag-net and the dip-net are two common instruments of capture. The drag-net is used in two ways. The net is set across the lower part of the marsh creek or river while the fishermen rout the terrapins out of the upper part of the river; the terrapins driven out in this manner go downstream with the tide and become caught in the net.

At high tide, when the terrapins are swimming about and feeding over the marshes, the reptiles are sometimes taken in dip-nets. The fisherman poles his skiff among the grassy areas, watching closely for terrapins which are found feeding on the small snails which live on the marsh grass. When a terrapin is seen, it is captured in the dip-net or crab-net.

A more common method of fishing is followed at low tide by men who wade the mud carrying a stick with which they probe into the soft mud in their search for terrapins which lie nearly buried.

Few fishermen engage in fishing for terrapin outside of the states of Louisiana and Mississippi; most of those taken in other states are caught accidentally by fishermen seeking fish or shellfish.

Marketing.

Most of the larger terrapin are shipped to Baltimore, New York, Philadelphia and other large cities. Those procured from the Chesapeake Bay, commonly called "Chesapeakes," average nearly 6 pounds each and command the highest prices, while those from the North Carolina region bring slightly less. The terrapins from Georgia, Florida and Alabama are much smaller than either the North Carolina or the Chesapeake species averaging only about three pounds each, and consequently sell at a much lower price. The Louisiana and Texas terrapins are sold at prices only slightly lower than those obtained for the "Chesapeakes."

At one time small quantities of terrapin were canned in Georgia but their rapid rise in price has placed their cost beyond the reach of the canner.

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Chapter 33.

Miscellaneous Shellfish Industries of the United States.

Scallops.

The beauty of the scallop shell attracted attention long before the food value of this shellfish was recognized. In ancient times, the savages used scallop shells for many decorative purposes. The first use to which the colonists put the scallop was as fertilizer. After severe storms, when these shellfish were washed ashore in large quantities, the New England farmers gathered them and spread them on their land. Later the farmers used scallops as a stock feed. About the year 1870, the edible qualities of this mollusk became known and an important industry gradually developed. At present, the scallop is classed as one of the delicacies among sea foods. The fishery has been prosecuted so vigorously that the natural supply is rapidly diminishing. The price of scallops, while it has varied from year to year depending on the catch, has steadily increased, whereas the annual catch has remained the same or declined slightly.

The present industry is located principally in Massachusetts and New York although small quantities of scallops are also produced in Maine, Rhode Island, Connecticut, New Jersey, North Carolina and other states along the Atlantic Coast. Small scallops are found from Cape Cod to the Gulf of Mexico. The giant scallop is found from Cape Hatteras to Labrador but is most abundant along the Maine coast and at one time was a formidable rival of the shallow-water scallop, but in recent years the deep sea scallop industry has declined until now relatively few are taken.

The latest available data relative to the production of scallops in the various states are presented in Table 81.

TABLE 81

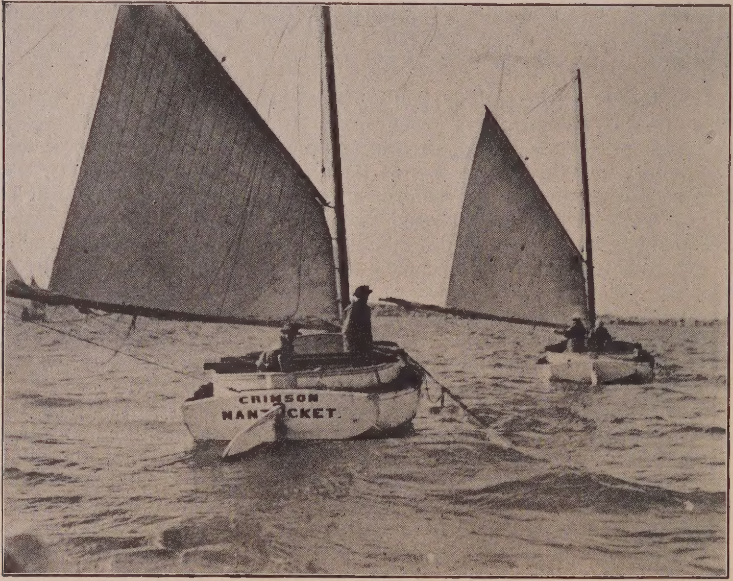
VALUE AND QUANTITIES OF SCALLOPS TAKEN

State	Year	Pounds	Value
Massachusetts	1919	1,332,486	$439,382
New York	1921	1,235,760	217,108
North Carolina	1918	* 422,832	31,618
Maryland	1920	113,760	26,852
Maine	1919	72,512	31,416
Connecticut	1919	38,400	13,717
Rhode Island	1919	33,994	14,608
New Jersey	1921	540	90

* The latest statistics for other states indicate none were taken commercially.

Species of Commercial Importance.

The scallop is a mollusk belonging to the *Lamellibranchia.* The family of *Pectenidæ* includes about forty species, four of which are found on the Atlantic Coast. Of these only two are of commercial importance. The common shallow water scallop found from Massachusetts to the Gulf of Mexico is the most important commercial species and is ordinarily designated as *Pecten gibbus,* var. *borealis* (Say) although it is also called *Pecten irradians.* In England, this scallop is called "fan shells," "frills," "queens," and "squims." The giant, deep-water scallop found from Massachusetts to Labrador is *Placopecten grandis* (Solander).



Courtesy Massachusetts Fish and Game Commission.

FIG. 219.—Dredging for scallops.

Several species of scallops are found on the Pacific Coast but the western scallops are not utilized commercially to any considerable extent.

Placopecten grandis has a bathymetrical range from 1 to 150 fathoms. Because of the depth at which this shellfish lives, comparatively little is known concerning its habits in its natural habitat. Drew[1] has carried out extensive investigations concerning the anatomy, physiology, and embryology of this giant scallop. *Placopecten grandis* possesses a much larger, smoother shell than *Pecten gibbus* and is therefore called the giant or smooth scallop. It is also called, from the habitat, sea scallop. The foot is relatively small, split at the end and possesses a large byssal gland.

[1] *University of Maine Studies, 6* (1906).

The sexes are separate. The embryos pass through a free-swimming stage after which they settle to the bottom and attach themselves to some object by means of a byssal thread in much the same manner as do the embryonic *Pecten gibbus.* The average length of life is in doubt; but this scallop probably does not live much longer than the shallow water scallop which seldom lives over two years.

The small scallop or bay scallop, *Pecten gibbus,* is found in shallow waters near the shore and is usually found where eelgrass is abundant. *Pecten gibbus* swims through the water in a zigzag course by closing its shell and discharging a portion of the enclosed water in a jet near one of the lobes of the shell on the hinge side. As the shellfish moves through the water, it rises as it rotates slowly and continues opening and closing its shell alternately discharging water near one lobe and then the other. When the scallop reaches the surface its muscular contractions cease and it sinks to the bottom again.

Scallops often lie on the eelgrass near the surface; when disturbed, they drop quickly to the bottom seeking protection.

Until recently, comparatively little was known about the life history of this scallop. In 1910, Belding[2] completed extensive biological researches on this mollusk. Unlike the giant scallop in which the sexes are separate, *Pecten gibbus* is hermaphroditic. The spermatozoa and ova are usually discharged alternately so that there is little danger of self-fertilization. Fifteen to twenty hours after fertilization the egg becomes a swimming embryo. The movements of its cilia keep it from sinking to the bottom and cause the embryo to rotate rapidly. A thin transparent shell secreted by the shell gland grows over the young scallop before it is 40 hours old. The young scallop does not take on the characteristics of the adult for 5 or 6 days after it has reached the veliger (swimming) stage. During the last three days of the swimming stage, a foot begins to develop on the under side of the body which aids in swimming. After its free swimming existence, the young scallop excretes a gelatinous substance which immediately hardens in the water and enables the scallop to attach itself by means of this thread called a byssus. As the scallop grows older, the foot gradually becomes smaller in proportion to the size of the shell, the mollusk takes on the characteristics of the adult, and begins to swim by opening and closing its shell. The scallops grow rapidly and are short lived; only a few live for quite two years. Scallops spawn when they are one year old, but few spawn more than once during their short life.

Because of the limited space, which is allotted the consideration of the scallop, a detailed description of the anatomy of this mollusk cannot be given. This subject is considered in detail in Belding's report referred to above.

The Chemical Composition of Scallops.

Atwater and Bryant[3] have analyzed nearly all the species of shellfish commonly eaten in America. Their analyses of scallops as purchased

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[2] *Rept. Scallop Fishery of Mass., Mass Commission Fisheries Game, 1910.*
[3] *U. S. Dept. Agr., Office Ex. Sta.,* Bull. *28* (1906).

TABLE 82

COMPOSITION OF SCALLOPS

	Water	Protein N × 6.25	Fat	Total Carbohydrates	Ash	Fuel Value per Pound
	Per cent	Per cent	Per cent	Per cent	Per cent	Cals.
Minimum	77.8	14.5	...	1.1	1.3	305
Maximum	82.8	15.1	0.3	5.6	1.5	385
Average	80.3	14.8	0.1	3.4	1.4	345

(adductor muscle) are given in Table 82. According to these figures scallops are higher in protein than any of the other common edible shellfish. However, it must be remembered, that only the adductor muscle of the scallop is eaten, whereas practically all the flesh of other shellfish is eaten.

Osborne and Jones[4] have hydrolyzed the edible portion of the scallop and determined the amino acids resulting as cleavage products; their results are given below and should be compared with those given on page 273 for halibut and chicken.

Glycocoll	0.00%
Leucine	8.78
Proline	2.28
Phenylalanine	4.90
Aspartic acid	4.37
Glutamic acid	14.88
Tyrosine	1.95
Arginine	7.38
Histidine	2.02
Lysine	5.77
Ammonia	1.08
Tryptophan	Present
	52.51

The Scallop Fishery.

The Small or Bay Scallop.

The scallop fishery is a seasonal industry since most states enforce a closed season. In Massachusetts, the closed season extends from April first to October first. Legal restriction of the fishing was introduced in Massachusetts in 1885 in an effort to stop the rapid decline of the fishery. The closed season permits the yearling scallops to spawn. Inasmuch as only a comparatively few of the scallops live to spawn the second season, if the small "seed" scallops are not disturbed there is no danger of overfishing. Massachusetts now prohibits the taking of the young "seed" scallops.

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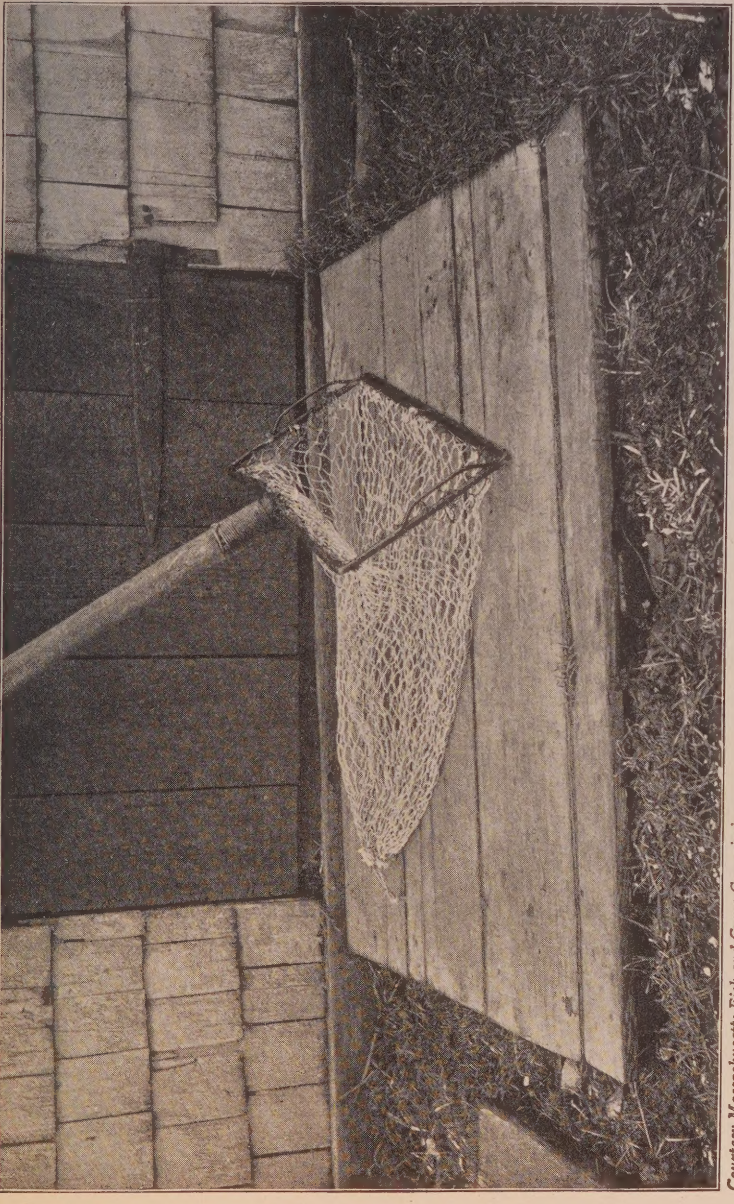
[4] *Am. J. Physiol., 24* (1909), 161-9.



Courtesy Massachusetts Fish and Game Commission.

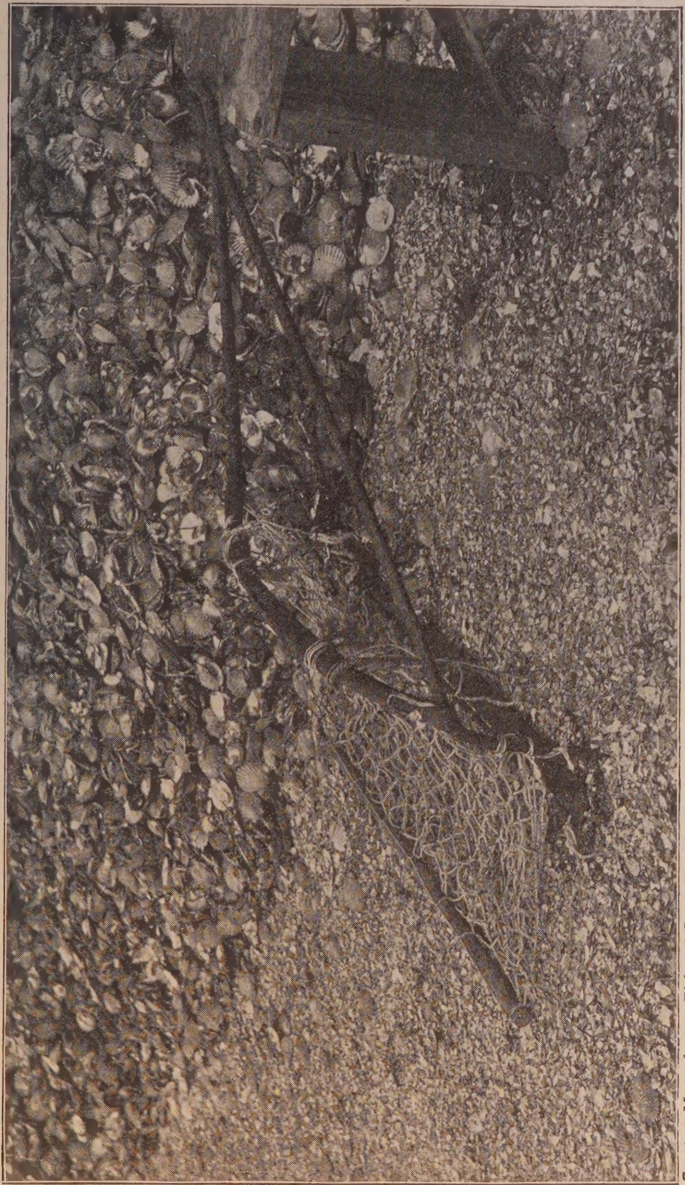
FIG. 220.—The scallop pusher.

Bay scallops are sometimes taken by an instrument called a pusher, which consists of a wooden pole from 8 to 9 feet long, attached to a rectangular iron frame 3 by 1.5 feet upon which is fitted a netting bag about 3 feet in depth. The fisherman, wading on the flats at low tide, shoves the "pusher" among the eelgrass and thus captures the scallops. When a bag-full of scallops is obtained, it is emptied into a dory, and the fishing is continued. Obviously, this method is applicable only to shallow flats and can only be worked at low tide; it is not very profitable and is being discarded for the more rapid dredging methods.

Scallops are mainly taken in dredges dragged along the bottom either by catboats (sailboats) or by power boats (gasoline boats). The common form of dredge used in Massachusetts consists of an iron framework about 3 by 1½ feet, with a netting bag attached which will hold from one to two bushels of scallops. A single catboat or power boat is used to pull 6 to 10 dredges across the scallop grounds. When the dredges are hauled in, their contents are emptied on a culling board projecting slightly on both sides. The scallops are culled or separated from the rubbish while the dredges are pulled back over the grounds. The culled scallops are first put into buckets and later transferred to bags or dumped into the cockpit of the boat. Two men are usually employed on the larger catboats and on the power boats, although one man alone sometimes does the work. Several styles of dredges are in common use. The "scraper" (see Fig. 221) is one of the most popular scallop dredges; it consists of a rigid triangular iron frame which has a curve of nearly 90° at the base. A raised crossbar connects the two arms. A strip of iron about 2 inches wide extends across the bottom and acts as a scraping blade being set at an angle so as to dig into the sand. The top of the net is fastened to the crossbar and the lower part to the blade. The usual dimensions of this dredge are: arms 2.5 feet; upper cross bar 2 feet; blade 2.5 feet. The wooden bar keeps the net from catching on the bottom. Usually the lower part of the net consists of interwoven iron rings.

The catch of scallops is ordinarily taken to the fisherman's shed or shanty where the scallops are opened and the "eyes" removed. The adductor muscle or "eye" is the only part of the scallop eaten. The remainder of the scallop is edible and has an agreeable flavor but prejudice rules that it is unfit for human consumption, so it is used for bait or fertilizer. An expert scallop opener can open 15 bushels of scallops in a day, and, since a bushel of scallops yields 2.5 to 3 quarts, produces from 9 to 11 gallons of scallop "eyes."

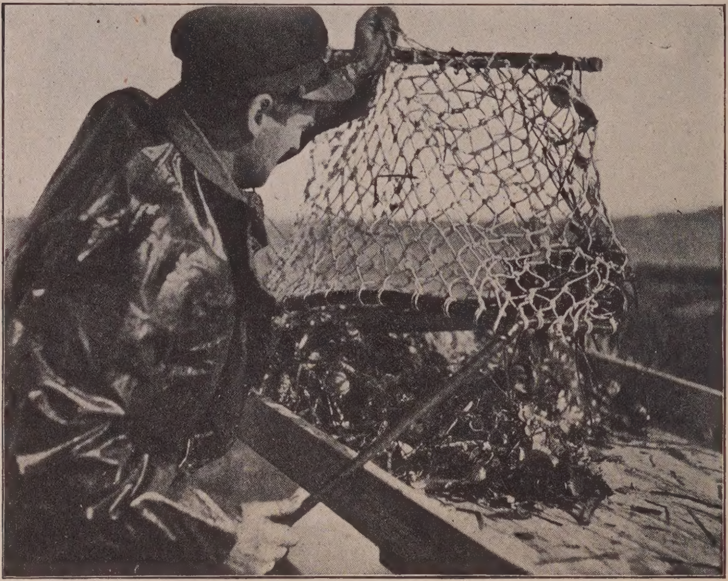
The scallops are nearly always soaked in water before they are marketed; this makes the eyes swell and become plump, thereby causing an increase in volume of about 40 per cent. This plumping process makes scallops very difficult to preserve; and, since plumped scallops spoil so easily, it prevents their shipment to distant markets. Yet, because nearly all consumers demand the large plump "eyes," the practice will probably be continued indefinitely. The scallops are sometimes swelled by placing about 4.5 gallons of eyes in a 7 gallon keg and filling it with fresh water; after standing over night, more water is added, and the scallops are shipped to market; upon arrival at the market, the scallops have increased



Courtesy Massachusetts Fish and Game Commission.

FIG. 221.—A scallop dredge, the scraper.

to the full amount of 7 gallons. Other fishermen place the scallops in shallow trays, cover them with water and allow them to stand over night; the following morning the plumped scallops are placed in tubs or kegs and shipped to market. Boston and New York City are the two most important markets for scallops. Because of the limited time which plumped scallops may be kept fresh, but few are shipped to inland cities.



Courtesy Massachusetts Fish and Game Commission.

FIG. 222.—Emptying the contents of the dredge on the culling board, where the scallops are separated from the eelgrass and other débris.

By-Products.

Less than ten per cent of the whole scallop is eaten, the remainder finds use in a variety of ways. The waste organic tissue is commonly used for fish bait, and considerable quantities of this material is preserved by salting for this purpose. Some of the refuse is used for fertilizer. The shells are often used for cultch to catch oyster seed or spat. Some shells are used in the construction of roads. Scallop shells are often used as ornaments. Various dealers in novelties use relatively large quantities of these shells in the manufacture of souvenirs and other ornaments. The lower valve or shell is the brightest and most beautiful and therefore is the only one used for ornamental purposes.

The Giant or Sea Scallop Industry.

Although giant scallops were taken in limited quantities along the coast of Maine, the fishery was not of commercial importance prior to 1883, when several large beds were discovered. Most of the beds that were discovered in the early days of the industry have long since been exhausted; many other beds have been located, but the fishery has been unable to supply the demand, and, in recent years, the quantity of these scallops taken in Maine has not exceeded 100,000 pounds of "eyes."

Because of the depth at which the giant scallops are found they are taken chiefly with dredges which resemble those used in the shallow water scallop fishery, consisting of a framework of flat iron bars to which is attached a bag or pocket which holds the scallops scraped up by the frame. The under side of the pocket is constructed of interjoined iron rings; the top and sides are made of twine netting. The pocket is usually about 4 feet in length and its width corresponds with that of the framework (3 to 4 feet). The rope attached to the "pull-bail" of the framework varies in length from 50 to 150 fathoms depending upon the depth at which the dredging is effected. Owing to the oblique position which it occupies, when in the water, it is much longer than the perpendicular distance from the boat to the bottom. Several dredges are dragged along the bottom either by a catboat (sailboat) or by a power boat. In certain localities, the dredging is carried out by men in row boats.

Recently a giant scallop fishery has developed along the Long Island seacoast and near the mouth of the Sound, off the New Jersey coast near Asbury Park, and along the coast of North Carolina. These beds are rapidly being depleted, for, in addition to dredges similar to those described above, large trawl nets are being used. Just how long these new fisheries will be profitable is problematical; the beds are widely scattered so new beds continue to be discovered.

The catch of scallops is usually taken to the fisherman's shed where the shellfish are opened and the adductor muscle or "eyes" cut out. One and a half bushels of scallops are required, on an average, to furnish a gallon of meats, which weighs about ten pounds. The giant scallop "eyes" are seldom plumped by soaking as are the shallow water scallops.

Portland, New York and Boston are the best markets for giant scallops. Smaller amounts are sold in Bangor, Augusta and Belfast, Maine.

The California Abalone Industry.

The Development of the Industry.

For many centuries abalones have been highly prized by the orientals, particularly the Chinese, but only in recent years have they been recognized as articles of food by Americans. The Chinese preserve abalones either by drying, or by drying and smoking. The interior of the abalone shell is very brilliantly colored mother-of-pearl, consequently the shells are valuable for ornamental purposes. The American Indians utilized the shells largely as ornaments and used pieces of the beautiful shells as money. In Europe and in the Orient, the shells are extensively employed in the making of inlaid work.

The early Chinese immigrants recognized that the California abalones were equally as valuable food as the oriental *Haliotis* and began to gather these mollusks for their meat, which they dried and smoked and exported to China and Hawaii. Soon the Americans began to gather up the shells which the Chinese discarded; these were polished and made into various ornaments. As early as 1879 an important industry had sprung up; in that year over $127,000 worth of abalones were taken. The canning of abalones was commenced about the year 1905 at Cayucos, California; and during recent years an important abalone canning industry has come into existence. In 1917, five plants packed abalones but in 1921 only three plants canned abalones. One of these plants was in East San Pedro and the other two were located in Monterey, California. 1,481,170 pounds of abalones were taken in California during 1921. While this mollusk is found all along the Pacific Coast from California to Alaska, the fishing is almost entirely confined to the coast south of Monterey Bay, California.

Physiology and Habits of the Abalones.

The abalone, also called sea-ear and ear shell, belongs to a family of marine snails, the *Haliotidæ,* of which six species and one variety have been found on the Pacific Coast, but none on the Atlantic Coast. These large mollusks have well-developed heads. Each abalone has a powerful, adhesive, creeping foot. Numerous contractile tentacles arise from the fringed epipodial fold around the base of the foot. The gills, alimentary system, kidneys, heart and blood vessels lie to the left of and behind the columellar muscle and foot.

Some abalones are taken in shallow water at low tide but they are more plentiful in water from 3 to 11 fathoms deep. The mollusks creep about on the bottom feeding on kelp and other seaweeds. If a chisel is slipped quickly under the abalone, it is easily detached; if, however, the diver hesitates, and the mollusk contracts its muscular foot, a powerful pressure is exerted and it is exceedingly difficult to pry the shellfish loose.

Fishing.

The Japanese are the most expert abalone fishermen. They go down in diving suits and detach the abalones from the rocks by slipping a steel chisel under the expanded foot of the shellfish. The diver puts his catch of abalones into a basket let down from the boat from which the diver fishes. When the net or basket has been filled with the shellfish, the diver gives the signal and the abalones are hoisted aboard. The basket is again lowered and the fishing is continued. Each diver works about three hours at a shift.

Some expert swimmers work without diving suits in water up to twenty feet in depth. They wear glasses to protect their eyes and put cotton in their ears. These divers are able to stay under water one to two minutes, and, when fishing on good grounds, bring up an armful of abalones each time.

The American fishermen usually row near the rocks in relatively shallow water and examine the sea-bottom through an instrument, consisting of a short wooden box with a pane of glass in the bottom. This device permits the examination of the sea-bottom without disturbance by surface ripples. When an abalone is found, it is pried off by means of a chisel fastened to a long pole, and raised to the surface.

A few Chinese fishermen wade in shallow water at low tide and collect in a basket any abalones that they may find.

Utilization of Abalones.

Fresh Abalones.

Although properly cooked abalone is one of the most delectable of shellfish, few Americans have acquired a taste for it. It is prepared for cooking by cutting it from the shell and trimming the visceral mass and the mantle fringe from the large central muscle which is then cut transversely into slices. These small steaks may be fried, stewed, or minced and made into chowder. The juice makes an excellent bouillon.

Dried and Smoked Abalones.

A large proportion of the abalones taken are cooked, dried, smoked and exported to Hawaii and China. The dried abalones are prepared chiefly by the Chinese and Japanese inhabitants of California. They remove the abalones from the shells and put them in brine for a few days. This operation removes the mantle fringe and aids in the preservation of the meat. After washing, the salted abalones are cooked for about a half hour in water just below the boiling point. The oriental workmen transfer the abalones to baskets and carry them to the drying frames where they are spread on shallow trays to dry in the sun. After four or five days, the abalones are cooked again for an hour. After the second cooking the shellfish are smoked with charcoal smoke for a day. They are rinsed in boiling water and finally dried for about six weeks; and, after rinsing in warm water, the dried abalones are packed for shipment.

This drying process causes a loss in weight of approximately 90 per cent. The dried abalones are brown, hard and tough, yet they can be sliced with a sharp knife. The Chinese stew this dried product after soaking, or grind it into a powder and use the pulverized abalone for the preparation of soup.

Canning.

The abalone is prepared for canning, after its removal from the shell, by cutting away the visceral mass, washing and then brining for about forty-eight hours. The black envelope around the foot is removed. For the American trade, only the foot muscle is minced and prepared for canning; but for the oriental trade both the foot muscle and the mantle are cut into cubes and canned.

The minced meat is packed into tin cans which are then exhausted for 45 minutes at a low temperature. The exhausted cans are sealed and sterilized in a retort under 15 pounds steam pressure for one hour. After the cooking, the cans are cooled with a spray of cold water, labeled and packed into cases. In California 2,186 cases of abalone valued at $15,496 were packed during the year 1921.

By-Products.

The shell products can scarcely be considered as by-products as they are of much greater value than the preserved meat. Many important articles are manufactured from the mother-of-pearl with which the shells are lined, including the following: cuff buttons, knife handles, paper knives, ink stands, buttons, and many other useful ornamental articles. This industry is described in Chapter 9.

Glue has been prepared from the viscera.

Pearls and blister pearls are often found in abalones.

Sea Mussels.

Possibilities of the Industry.

Sea mussels are widely distributed along the coast of North America, being abundant on the Atlantic Coast from North Carolina northward and on the Pacific Coast from San Francisco to Alaska. They usually grow in large beds on the surface of mud or sand along the low tide mark and often extend to a level several feet below low tide water; they are also found in deeper water up to 100 fathoms in depth.

Curiously while the oyster, clam and scallop have been commercially exploited in America in a large way, the sea mussel, which is such an important European shellfish, has been neglected. Some are sold in the shell in the New York, San Francisco, Seattle and other important fish markets but they have never come into general use as a food. Only one cannery packed mussels in 1921, and the value of the pack was a relatively small sum. A small quantity of mussels are preserved by pickling in vinegar. Mussels have a limited use as fertilizer, and some are used as fish bait. The latest available figures relative to the production of sea mussels by states are given in Table 83.

TABLE 83

PRODUCTION OF MUSSELS IN THE UNITED STATES

State *	Year	Quantity	Value
New Jersey	1921	791,000 lbs.	$6,070
New York	1921	50,000	2,500
California	1915	19,240	2,326
Maine	1919	16,970	367
Rhode Island	1919	10,000	1,000
Washington	1915	700	83

* In other states the latest statistics available indicate that mussels are not taken commercially.

In Europe, the demand for mussels for food and bait is so great that the natural supply is unable to meet it; therefore much attention has been given to mussel culture. Great Britain and Ireland consume annually about 35,000,000 pounds, Holland about 65,000,000 pounds and France approximately 400,000,000 pounds of mussels. Thousands of "bouchots" or mussel hedges dot the French coast. French mussel culture dates back to the thirteenth century when an Irishman named Walton is said to have originated the "bouchot" system which has been successfully applied ever since. Walton observed that mussels grew larger and finer flavored on stakes than on the mud of the flats. He therefore constructed a double hedge of stakes along the low tide mark which offered a large surface for the growth of mussels.

Species of Mussels Utilized.

Two important species of mussels are found on the North American coast; *Mytilus edulis* Linnæus occurs on the Atlantic Coast as far south as North Carolina, while this species and a closely related species *Mytilis californianus* Conrad are found on the Pacific Coast from Alaska to San Francisco. The latter when full grown is much larger and has a rougher shell than *Mytilis edulis.*

The favorite habitat of these mussels is at the low tide mark in slightly brackish water, along swift tide ways and in protected bays and estuaries. Mussels often attach themselves to the piles and timbers of bridges, wharves, and other objects, rocks and buoys.

The internal structure of mussels bears a general resemblance to that of the clam and many other bivalves. The mussel is characterized by the small, strong, triangular foot and especially by the strong and prominent byssus or "beard." The byssus enables the mussel to attach itself firmly to the shell of another mussel, to a rock or some other object. A viscous liquid is excreted by glands, under and behind the foot, which solidifies as soon as it comes in contact with the water, thus forming a thread. A number of the threads form the "beard" which enables the mussel to anchor itself firmly and thus prevents being washed away during storms. Many thousands of mussels are often seen thus attached to each other lying on the flats at low tide; they sometimes cover several acres of tidal flats giving them a black appearance. The foot of the mussel is a brown or purple colored muscular organ; its tip is able to exert suction by means of which the mussel is able to take firm hold of any hard object.

Mussels feed on diatoms and other microscopic forms, larvæ, etc. They grow rather slowly, requiring from one to eight years to reach maturity. In Europe seed mussels, 2 to 3 years old, are often collected and planted until they reach marketable size; this requires from 2 to 5 years. The rate of growth depends upon the temperature, the amount of food and the rate of movement of the water. The most rapid growth is usually obtained, other conditions being equal, in the bottom of the tidal streams where the mussels are never uncovered, and where there is no deposition of silt. Under such conditions mussels occasionally reach a length of 3 inches in a single year.

Composition of Sea Mussels.

The edible portion of mussels contains a relatively large amount of protein compared to oysters and clams. The edible portion of scallops contains a higher percentage of protein, and that of oysters contains more carbohydrates. But since the mussel shells are thin and light, the proportion of refuse is much smaller and so the total amount of nutrients in a bushel of mussels is considerably greater than in the same quantity of any other common shellfish.

Field[5] reported experiments by Alsberg, and Clark and Bennett which indicate that sea mussels are about as easily digested as hard-boiled eggs and nearly as completely digested as raw beef.

The composition of whole mussels and the edible portion of mussels is given in Table 84.

TABLE 84

COMPOSITION OF SEA MUSSELS

	Refuse Per cent	Water Per cent	Protein N × 6.25 Per cent	Fat Per cent	Total Carbohydrates Per cent	Ash Per cent	Fuel Value Per Pound Cal.
Whole mussels *	46.7	44.9	4.6	0.6	2.2	1.0	150
Whole mussels †	46.69	41.1	5.0	0.8	0.85	...	140
Edible portion *	.....	84.2	8.7	1.1	4.1	1.9	285
Edible portion †	.....	83.27	10.18	1.64	1.74	1.99	299

* Atwater, W. O. and Bryant, A. P., "The Chemical Composition of American Food Materials." U. S. Dept. Agr., *Office Ex. Sta. Bull., 28* (1906).

† Field, I. A., *Bureau Fisheries, Bull. 29* (1909), 85-128.

Methods of Fishing.

Mussels are very easily taken, in most cases, as they often lie attached to each other in huge beds in relatively shallow water. Dredges are ordinarily used in taking this shellfish and usually yield large returns for the amount of labor expended. Because of the danger of contamination with decomposition products, mussels that are exposed at low tide are seldom taken for food.

In Europe, rakes as well as dredges are used. Rakes are usually considered the better as they do not crush the shells nor cause the sand to shift over the bed. The common rake has a breadth of 18 inches, with teeth 1 inch apart, is attached to a pole 20 to 25 feet long, and has a wire net bag behind it for holding the catch.

Utilization of Mussels.

Fresh.

Mussels spoil very quickly after they have been removed from the water. Shucked mussels cannot be kept fresh in an ice chest for longer than 24 hours. This is the most serious drawback to the development of trade in fresh mussels as they cannot be shipped long distances. Mussels are ordinarily marketed alive in the shell, and are shipped in barrels like clams, being kept alive by covering with wet cloths and storing in cool dark places.

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[5] ***Bureau Fisheries Bull. 29*** **(1909), 85-128.**

Mussels are best from December to July; they therefore may be used as a substitute for oysters during the early summer.

Mussels are eaten entire except the shell and the beard or byssus. The byssus is usually detached after cooking. Mussels may be stewed, steamed, roasted, fried, creamed and made into croquettes, fritters and chowder.

Pickled Mussels.

Pickling is the most common way of preserving mussels. After washing, the mussels are steamed until the shells open. The meats are then taken from the shells and the beards are pulled off. The mussel meats are placed in a bowl and covered with spiced vinegar which usually consists of a mixture of vinegar, onions, black pepper, red pepper, cloves, salt, allspice, olive oil, garlic, etc. When thus prepared, they will keep for a week or two if kept in a cool place. Pickled mussels are also prepared without steaming, but this process is not as common as the one described above.

Pickled mussels are also canned. After washing, steaming and removing from the shell, the beards are pulled off. The liquor formed during the steaming process is mixed with spiced vinegar. Field recommends that for each quart of natural liquor the following ingredients be added: 1 pint vinegar, ½ oz. cinnamon, ¼ oz. cloves, ¼ oz. salt and 1 small red pepper. This mixture is allowed to simmer for fifteen minutes and is then poured over the meats. After standing a day, the meats are removed from the spiced liquor and are packed in bottles or jars. The liquor is filtered, heated to boiling, and poured over the meats in the jars. After sealing, the jars are heated in an autoclave with 5 pounds steam pressure for 15 minutes.

The Canning of Mussels.

At one time three canneries in the United States packed mussels but in 1921 only one plant, located in Smith River, California, canned mussels. In 1922, 2,500 cases were packed in New York. The method of canning mussels was devised by Field[6] and is as follows:

> The mussels when taken from the collecting boats are rapidly picked over by hand to eliminate any dead or unhealthy ones which may be present, as well as the coarse adhering debris. Then they are placed in a cleaning apparatus. . . .
>
> After this treatment the mussels are removed and rinsed off with clean water. They are placed in a chest and subjected to live steam for from 5 to 10 minutes, or until the shells begin to open. They are next emptied out into shallow pans to cool and the natural liquor which has escaped into the chest is preserved in a separate dish. As soon as they are cool enough to be handled the mussels are shucked and the horny "beard" removed, the meats and liquor being preserved in separate dishes.
>
> While the liquor taken from the steam chest and that taken from the mussels

[6] *Bureau Fisheries Bull. 29* (1909), 11-13.

during the process of shucking is filtering through a fine meshed cloth, the mussel meats are packed in glass jars or bottles. The filtered liquor is brought to a boil and two ounces of salt are added for each gallon. The jars containing the meats are then filled with the boiling liquid and sealed. To insure complete sterilization, the sealed jars are placed in a steam chest and subjected to 5 pounds pressure for 15 minutes. They are allowed to cool down slowly and when the temperature has fallen to about 100 degrees F. they are removed and set aside for future use.

Canned mussels possess an attractive appearance and pleasing taste. They do not shrivel when canned as do oysters, but remain tender and retain the full flavor.

The dehydration of mussels has been studied by Field[6] and others but has never been applied commercially.

Other Uses for Mussels.

In Europe, large quantities of mussels are used as fish bait. Their use in America for this purpose is very limited. Mussels and mussel muds (mussel beds buried with silt) are used as fertilizer where they may be obtained easily in large quantities. Both mussels and mussel muds are used by the truck farmers along the coast in New Jersey and Long Island. Large quantities of mussel mud are used on Prince Edward Island where extensive deposits varying from 5 to 25 feet in depth are found. The shells, usually more or less intact, are found imbedded in dense deposits of silt. The mussel mud is obtained by means of dredging machines operated from rafts. It contains organic matter, lime and small quantities of phosphates and potassium compounds and is an excellent fertilizer for acid or wornout soil.

Recently, a new method of utilizing sea mussels has been developed in Denmark. The mussels are dried at a high temperature and then ground. The meal produced is considered an excellent feed for chickens. One sample contained the following constituents: calcium salts 71.41%; carbohydrates 13.21%; nitrogenous matter 11.64%; fat 1.68% and water 2.06%.

Feeding such material is an excellent way of feeding grit for strengthening the egg shells as a considerable amount of nutritious feed is obtained from the dried mussels.

Other Shellfish Industries.

Small quantities of many other marine mollusks are utilized commercially, including the following: natica, cockle, periwinkle, piddock, squid, donax, cephalopods, and chiton.

Perhaps the most important of these mollusks is the squid which is commonly used as bait by many of the trawl and hand line fishermen of New England, Eastern Canada and Newfoundland. This mollusk belongs to the devilfish family and is a favorite oriental marine delicacy. Squid is used chiefly as bait on the Atlantic Coast, but on the western coast it is marketed fresh, dried and canned. In August 1922, over a million pounds of the mollusk was held in cold storage. The common squid, *Loligo opalescens* Barry is eaten chiefly by the Chinese and Japanese inhabitants of the Western states and by the Italian and Spanish of New York and Boston.

In California, squid are now taken usually in the large lampara nets used for sardines, and under similar conditions; i.e., at night, since by day, or even on moonlight nights, they see the nets and avoid them. When a school is located the net is thrown around them and they are drawn to the boat and the net emptied the same as with sardines.

Squid is sold fresh in most of the important fish markets of California, Oregon and Washington, and in New York City. Only one California cannery packed squid in 1921, but in Spain considerable quantities are canned in olive oil. The most important method of preservation is sun-drying, and considerable quantities of this mollusk are preserved in California in this manner for the oriental trade.

Methods[7] of drying squid vary, according to quality of product desired. The best quality of selected squid must be at least medium large size, 10 to 18 inches in length. They are split, the pen and ink bag removed, are scraped, and then spread out flat on the ground and dried, with very little or no salt. They are frequently turned, generally by hand, and when thoroughly dried and hard, are packed in barrels or in boxes and shipped to market.

The cockle industry of Europe is one of the important shellfisheries of that continent and is particularly important on the coasts of the British Isles, yet in America this shellfish is almost neglected. The common cockle, *Cardium corbis,* is common along the northwest coast from Coos Bay, Oregon, northward. Fresh cockles are eaten to a limited extent in Oregon, Washington, British Columbia and Alaska. Some cockles are canned in the vicinity of Tillamook Bay and sold as clams.

Periwinkles and whelks are commonly eaten in Europe, but the American species are seldom utilized for any purpose. The most important Atlantic species *Buccinum undatum* Linn, is found from Cape Cod northwards. *Buccinum aleuticum* Linn, is common along the Alaskan coast. The small periwinkle *Littorina litorea* is found in abundance on all our coasts. Both *Buccinum undatum,* the English whelk, and *Littorina litorea* Linn, the English periwinkle, are taken in large quantities on the coasts of the British Isles.

The piddock is found in the United States along the eastern coast from Cape Hatteras southward, and is commonly eaten in the West Indies. This mollusk, *Pholas costata,* is larger than the European species *Pholas dactylus,* which is utilized for food by the French, particularly those living along the coast of Normandy.

The moonshell, or natica, is one of the common shellfish on both the Atlantic and Pacific coasts; where it occurs from New Jersey to Maine and from California to Alaska. Although this mollusk is a very good food, little use has been made of it.

On the Florida and southern California coasts the donax (*Donax lævigata* Deshayes) is found in considerable quantities. The shells are short and stumpy, cut nearly off at one end and taper to a rounded point at the other, being less than an inch in length. This mollusk varies from white to a purple color. These shellfish are used principally in the preparation of soup which is prepared by boiling the entire mollusks in a large pot of water. The soup is strained from the shells and is occasionally canned.

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[7] Coleman, R. A., *Bureau Fisheries, Mem. S240,* 1923.

There is a small trade in octopus on the Pacific Coast. The most abundant species is *Polypus hongkongensis;* small individuals of this mollusk are found in shoal water and much larger ones in deep water. Some are caught in the Puget Sound and along the California coast. The octopi are usually caught in traps resembling those used in the crab fishery; they are sold chiefly to the orientals who make them into soup. Some are preserved by sun-drying without salt.

A number of species of chitons are found on the Pacific Coast, none of which is utilized to any great extent. The black chiton (*Katherina tunicata* Gray) is gathered and eaten by the natives of Alaska. The giant chiton (*Cryptochiton stelleri* Middendorff) is found on the California coast. Its chief use is in the making of curios such as toy boats and electric lamp shades.

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Chapter 34.

The Whaling Industry, Porpoises and Dolphins.

Whales.

Characteristics.

Whales are in many respects the most interesting and wonderful of all living creatures. They belong to a much higher order than any of the marine forms thus far considered. A brief consideration of their characteristics may, therefore, not be out of place even in a work of this nature.

Whales are found in all the seas and formerly were relatively abundant, but, since 1864, have been hunted with such effective means that many species are already threatened with extinction.

Whales are mammals having a body, fish-like in form, without a distinct neck. The head is generally large, in some species attaining to even more than one-third the entire length. The aperture of the mouth is always wide.

The surface of the skin is smooth and glistening, being devoid of hair. Immediately beneath the skin and connected with it is a thick layer of fat called blubber, which serves the purpose of the hairy covering of other mammals in retaining the heat of the body.

The eye is small and seems ridiculously so when compared with the size of the animal. There is no external ear, there being only a very minute aperture in the skin situated a short distance behind the eye, yet, because water transmits sound so well, they hear remarkably well.

The whale was once commonly supposed to be a fish, and the idea persists in the popular mind with remarkable tenacity. It is as essentially a mammal as a horse or a cow, and simply resembles a fish externally because it is adapted to inhabit the same element; but it is no more on that account a fish, than a bat is a bird.

Anyone doubting the Darwinian theory of evolution would do well to study the whale. The inevitable conclusion of the student is that the whale has gradually developed from a different creature having legs. The flippers of the whale are, in fact, fore-limbs functionally reduced to mere paddles with no power of motion except at the shoulder joint and have beneath their smooth and continuous external covering all of the bones, joints, and even most of the muscles, nerves and arteries of the human hand and arm.

Their organization necessitates passing their life entirely in the water, as on land they are entirely helpless. They must, however, rise very frequently to the surface for the purpose of respiration. Their principal instrument of locomotion, the tail, is expanded horizontally in order to facilitate their constant upward and downward motion. The respiratory orifice or nostril is on the highest part of the head, thus it is the only part of the body of which the exposure above the surface is absolutely necessary. The moment the animal rises to the surface it forcibly expels from its lungs the air taken in at the last inspiration, which is highly charged with water vapor in consequence of the natural respiratory changes. The vapor rapidly condenses in the colder atmosphere, forming a column of condensed vapor or spray which is often erroneously taken for water and accounts for the false idea that whales spout water taken in at the mouth.

Because whales live in a supporting medium, their young are enormously large at birth. Chapman records taking a 25-foot baby which weighed about 8 tons from an 80-foot blue whale. Usually one young is born at a time, rarely two and never more than two.

The whalebone whales have no teeth, but the palate is provided with numerous transversely placed horny laminæ or baleen which enable the whale to strain from the water the small animals upon which it feeds.

All whales are predatory animals, subsisting on living animal food of some kind, but one genus alone, the killer whale (*Orca*) eats other warm-blooded animals, as seals and whales. Some feed on fish, others on small floating crustaceans, while the principal staple of the food of many is constituted of the various species of cephalopods which abound in certain seas in vast numbers.

Economically Important Species.

Eleven commercially important whales are found in various seas. Certain of these species have been hunted for many centuries and are becoming rare. The order *Cetacea,* whales, porpoises, etc., is subdivided into two suborders, one being *Mystacoceti* to which the whalebone whales belong, the other being *Odontoceti* and includes the toothed whales, e.g., the sperm whale.

The Baleen or Whalebone Whales.—The Greenland right whale (*Balæna mysticetus*) has been hunted for many centuries in the Arctic regions until it was once considered extinct. The whalebone has a length up to 15 feet, 300 to 400 pieces on a side, and commands the highest price on the market, owing to the length and quality.

The Nordkaper whale, or Biscay right whale (*Balæna biscayensis*) is somewhat smaller than the Greenland right whale. It is most frequently found in the North Atlantic off Ireland and the Hebrides but has been taken off Shetland, Faroe and Iceland. The whalebone is of a quality similar to that of the Greenland right whale but its length is seldom more than 7 feet.

The southern right whale (*Balæna australis*) is found in the Antarctic. It has a length of 45 to 50 feet and whalebone measuring up to 7 feet in length.

The humpback whale (*Megaptera nodosa* Bonn) is found nearly all over the world, but especially in the South Atlantic off the coasts of South Africa and South America and off the coast of California. It is now the only species of commercial importance taken by the coastal whaling steamers of California. It is about 50 feet in length, being short and thick and having a large head with a flat forehead.

The blue whale (*Balænoptera musculus* (Linn)) is the largest living animal, and probably the largest animal which ever lived. The largest authentic specimen on record had a length of 87 feet. It is found in almost all seas and probably is today the species of greatest commercial importance. 2,268 blue whales were captured in the 1917-1918 season by the whalers operating in the vicinity of the Falkland Islands.

The finback whale (*Balænoptera physalus* (Linn)) is also of cosmopolitan distribution and is one of the important whales taken in such large numbers in the vicinity of the Falkland Islands. Its average total length is 62 feet, the maximum being 81 feet.

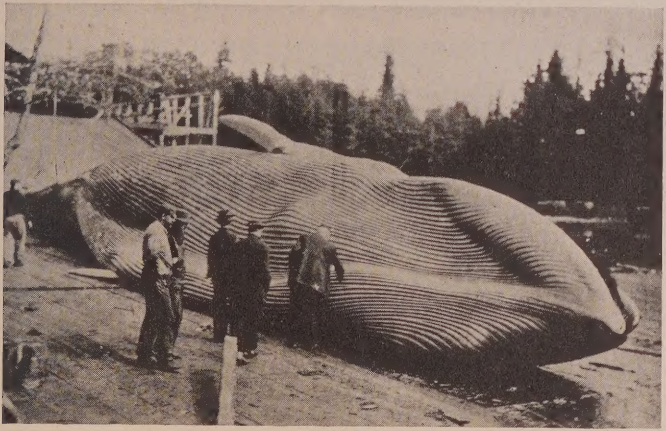

FIG. 223.—A large blue whale hauled up on the slip.

The sei or fish whale (*Balænoptera borealis* (Lesson)) is of moderate size, seldom exceeding 53 feet in length. It is principally captured off Scotland and the Faroe Islands, in the north, and the Falkland Islands in the south. It is of little commercial value, and is only pursued when there is a scarcity of the larger species.

The bottlenosed whale (*Balænoptera hyperoodon*) is a very small whale having a length of about 20 feet. It is found principally in the Norwegian Sea from April to July.

The California gray whale (*Rhachianectes glaucus* (Cope)) formerly was found on the coast of California in large numbers, and was once thought to have been exterminated, but recently many have been found in Japanese waters. Its average size is 40 feet, with a maximum length of 49 feet.

The Toothed Whales.—The cachalot or sperm whale (*Physeter macrocephalus* (Linn)) is the most important species of this suborder. It is found on both sides of the equator but has also been killed in the temperate and cold zones as far as Iceland in the north and South Georgia in the south. In its unusually large head is found the valuable spermaceti and sperm oil. Its usual length is between 50 and 60 feet.

The white whale (*Delphinapterus leucas* Pallas) is found only in the Arctic regions. It is rather small, usually being about 20 feet in length, and is therefore of little commercial importance.

The Industry.

Location and Importance.

The invention of the harpoon gun by Svend Foyn in 1864 and the ever increasing demand for meal and fertilizers have completely revolutionized the whaling industry. Formerly whaling was an extremely dangerous occupation, as the whales were hunted by men in small boats with hand harpoons and lances. When a whale was killed the whaling vessel came alongside, the valuable blubber was stripped from the carcass and hauled aboard; and the whalebone was removed from the mouth. After all of the blubber and oil had been removed, the carcass was abandoned. The oil was rendered in try-works built of brick between the foremast and the mainmast. In those days but three species, the sperm, bowhead and right whale, were hunted. In the old days the American whaling industry was centered in Massachusetts, New Bedford being

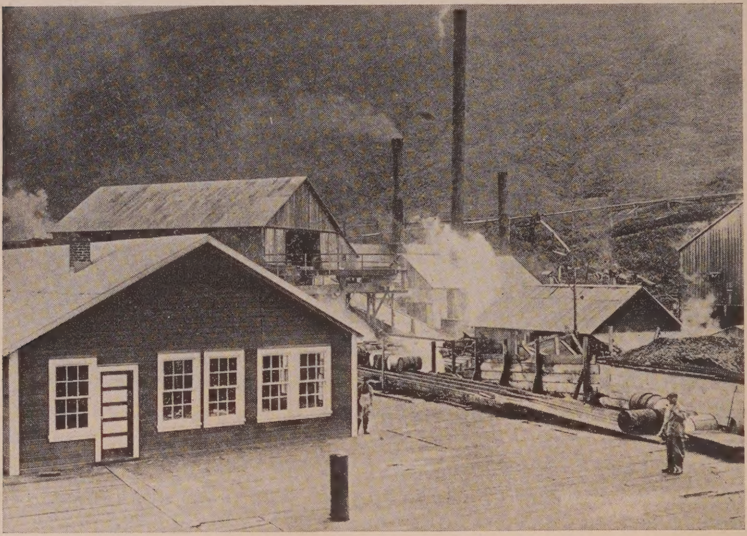

Fig. 224.—General view of the Pacific Sea Products Company's plant at Akutan, Alaska.

the home port of a magnificent fleet of sailing vessels. In 1850, 736 American vessels were engaged in whaling and returned with 14,744 barrels of sperm oil, 39,215 barrels of whale oil and 894,700 pounds of whalebone.

Now all has changed, steam vessels are employed, which capture the whales by means of large powerful harpoon guns. The fin, blue and other speedy whales can be taken, thus greatly increasing the quantity of whales available. The captured whales are towed to a shore whaling station where they are cut up and completely utilized for the manufacture of commercial products. Meat and fertilizer have become products rivaling in value that of the oil obtained.

The harpoon-gun method of capturing whales has proved to be very effective, so rapidly are the whales killed that the whaling grounds are quickly exhausted. Therefore the location of the industry is continually changing.

Andrews[1] estimated that the whaling industry yields an annual revenue of nearly $70,000,000. The return varies greatly, depending upon the number of whaling ships operating, the abundance of whales, and the price of the products. After a bad year, ships often remain idle for a year or two.

To-day, the most important whaling region is in the vicinity of the subantarctic islands known as the South Shetlands, South Orkneys, Falklands, South Georgia and Kerguelen. Near these islands 4,305 whales were taken in the 1917-18 season, the species being as follows:

Blue	2,268
Fin	1,771
Humpback	131
Sei	49
Right	48
Sperm	37
Bottlenose	1

In this district, about half of the world's catch of whales are killed.

Formerly, when the Greenland right whale was more plentiful whaling was extensively carried on in the Arctic regions by vessels from Norway, Scotland, England, Newfoundland, the United States, and other countries. Now comparatively few whales are captured in this region. Some whalers continue to operate from Iceland, Spitzbergen, Norway and Newfoundland.

The Scotch capture about 500 whales annually off Shetland, some are also taken off the Faroe Islands and off the Hebrides. Other important whaling areas are the Behring Sea, the Australian coasts, the coasts of Chile, Southeast Africa, West Africa (Elephant Bay), East Africa (Mozambique) and northern Japan.

The Norwegians are foremost in whaling, and capture about half the world's annual catch. In 1912, sixty Norwegian companies operated 157 whaling steamers with eleven transport vessels, thirty-seven floating factories, thirty shore stations, nine fertilizer works and thirteen factories for the preparation of canned whale meat and cattle food products. Their operations were carried on in all the important whaling areas.

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[1] Whale Hunting with Gun and Camera. New York, 1916.

Other countries possessing important whaling interests are Japan, Scotland, the United States and Newfoundland.

Methods of Capture.

The most approved type of steamer used in whaling is from 100 to 115 feet in length, with a breadth of from 18 feet to 21.5 feet, decked all over, and cut away at the bow and stern in order to enable her to turn quickly. The usual speed is about twelve knots. A harpoon-gun is mounted upon a heavy iron support at the very bow. The cannon is short, being about 50 inches long, with a bore of 3 or 3½ inches, and turns easily upon a swivel up and down and from side to side.

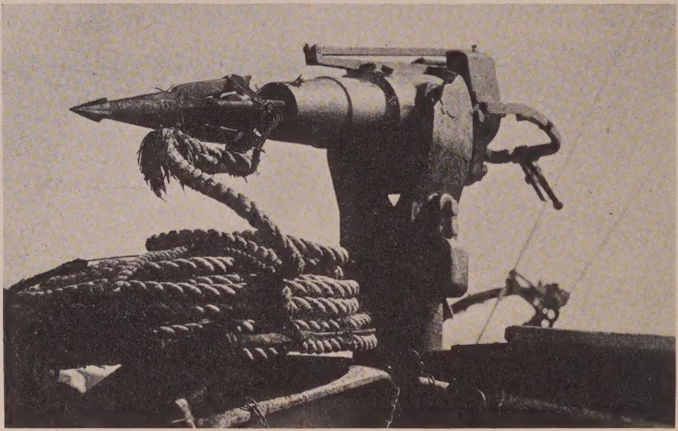

Photo by E. C. Johnston.

FIG. 225.—Loaded harpoon gun.

The harpoon is of the best Swedish iron and is about 6 feet in length with a weight of a little over 100 pounds. It has four prongs, which spring out at right angles to the harpoon when the line is tightened after the harpoon is lodged in the whale's body. On top of the harpoon is screwed a cast-iron head or shell, of conical shape, about 14 inches in length and weighing about 11 pounds. This shell is loaded with powder and exploded by a time fuse three seconds after the harpoon has left the cannon. A large ring slides along the double shaft of the harpoon, and to this, one end of a 4 or 5-inch rope is fastened. Forty to sixty fathoms of a somewhat lighter line are coiled on a heavy iron pan just under the gun, giving slack to be carried with the harpoon as it flies through the air.

From the pan, the rope passes over a roller in the bow of the ship to a double winch and down into the hold where a thousand fathoms or more are carried. By means of the winch, the whale is played, as one would use a reel on a fishing rod, and, after the animal has been killed, it is hauled to the surface and fastened to the side of the ship.

The whale is usually sighted by a lookout in the crow's nest on the mast. The steamer goes in the direction of the spot where the whale was seen, but long before this is reached the whale has sounded and the vessel moves towards the vicinity where the whale is expected to rise to spout.

Gradually the distance between the whaler and the whale is lessened until the gunner gets within range, which is fifteen or twenty yards. If the harpoon strikes a vital spot, the whale is killed outright. More often the whale dashes away until halted by the line, and even then sometimes tows the vessel for hours. The whale flesh is rather tough, so the harpoon seldom pulls out unless the animal was not hit squarely. When the captured whale tires, it is usually killed by a lance, after which it is fastened to the ship's side or towed behind.

Where whales are abundant, as in the vicinity of the Falkland Islands, one steamer may capture as many as ten in a single day. In northern latitudes, seldom more than four are taken in a day.

Butchering.

The methods employed in the "cutting in" or butchering of whales are much the same in the various shore stations.

When the whaler arrives at the factory, the whales may be anchored to a buoy until the factory is ready for them. Then a large chain connected to a cable is attached round the tail, and the whale is slowly hauled up on the flensing-slip by means of a steam winch. The animal floats back down, due to the accumulation of gases in the abdomen, and is therefore drawn up on the slip back or side down.

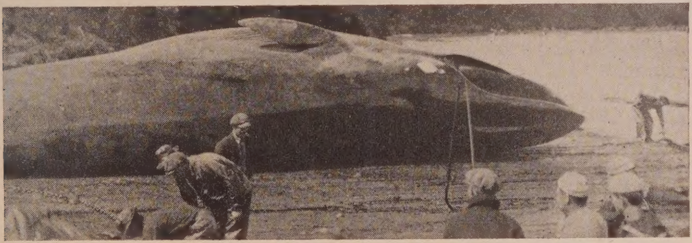

Photo by E. C. Johnston.

FIG. 226.—A large whale ready to be flensed.

The first operation is the stripping off of the blubber which lies just under the skin. The blubber is cut through along the mid-dorsal and ventral lines, two cuts being also made on each side. There are thus three strips taken off each side of the whale. A chain fastened to a cable is attached to the head end of each of these strips, the blubber being stripped off from the head end towards the tail by the assistance of a steam winch, the flensers using their knives to insure the blubber coming off without the meat.

The strips are then cut up into manageable blocks by laborers. The blocks are further divided, usually by means of revolving knives, into fairly small pieces ready for the boilers.

After the blubber is removed, a "meat-flenser" cuts off the whale's head and chops it up. The carcass is split open by chopping through the ribs of the upper side. A heavy hook is then attached to the tongue bones at the throat and the entire mass of heart, lungs, liver and intestines drawn out at once. The meat-flensers also strip the meat from the bones, the whole of the meat being taken off in four strips, two on each side. Finally, the backbone is cut up, and, after the whole of the meat and bones have been cut into small pieces, they are hoisted by elevators and dumped into boilers.

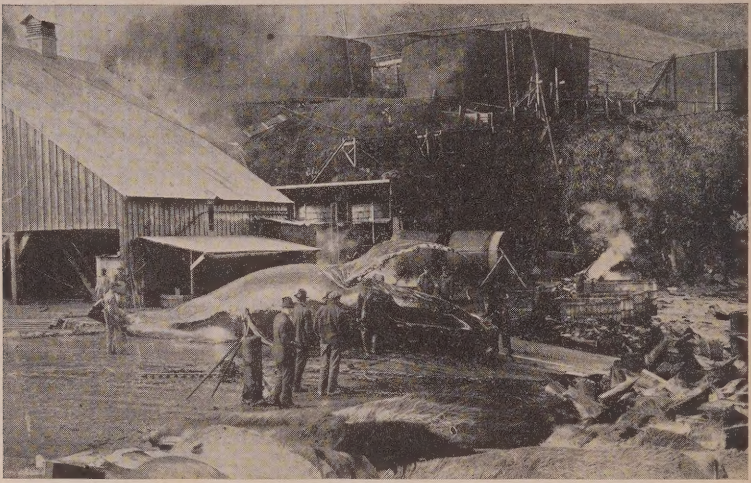

FIG. 227.—A humpback whale on slip. Note the baleen in foreground.

Meat for Man.

Whale meat plays an important part in the dietary of the Japanese. Hundreds of tons of whale flesh are sold in the market of all the large towns and villages. Much whale meat is canned and sold in all parts of the Empire.

Fresh whale meat is eaten in Norway, particularly in Trondhjem.

For many years, whale meat has also been canned in New Zealand.

During the World War whale meat began to be used in America to replace beef and other domestic meats. Most of the fresh and frozen whale meat was marketed in the large cities on the Pacific Coast, although it was also sold in New York and other eastern cities where it was served on the tables of some of the large hotels, but it was more of a curiosity

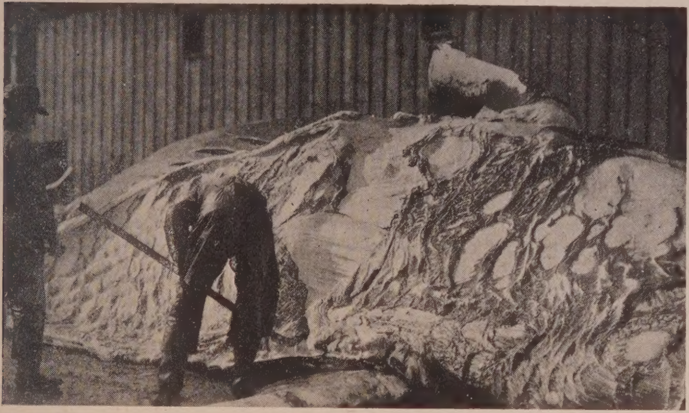

Photo by E. C. Johnston.

FIG. 228.—Stripping off the blubber.

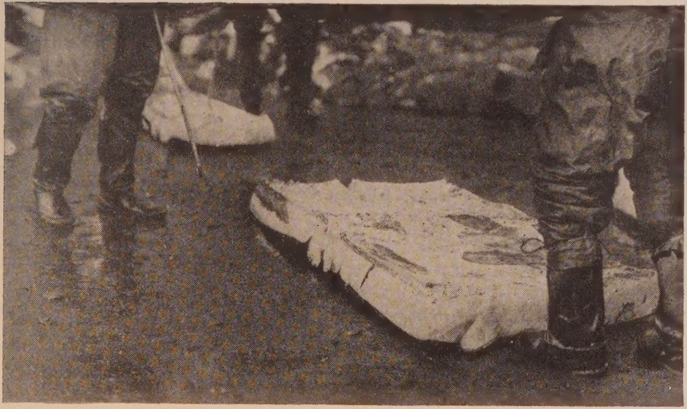

Photo by E. C. Johnston.

FIG. 229.—A strip of blubber.

than a regular staple of diet. At present the amount sold is extremely limited.

In handling the meat, it is cut from the whale in chunks which are cut into strips of about 45 pounds each, chilled and packed in boxes, three strips to the box.

The flesh is somewhat similar in appearance to beef, although it is darker and coarser grained and tastes somewhat like venison although it has a flavor peculiarly its own. The humpback is the best species for eating, but the finback, sei, beluga, and California gray also furnish excellent meat. A humpback whale yields about 6 tons of edible meat, a sei whale 5 tons and a finback about 8 tons.

It is cooked in much the same way as beef. The best results are said to be obtained by cooking slowly a long time with moist heat at a low temperature and with liberal seasoning. Roasts, pot roasts, and steaks are popular whale dishes.

The Japanese eat it in a variety of ways but perhaps it is most frequently chopped finely, mixed with vegetables and eaten raw, dressed with a brown sauce.

Nutritive Value.—Fresh whale meat contains about 71.2% of water, 23.1% of protein, ash 1.2%, and 4.2% of fat.

An analysis of canned whale meat gave the following results: Moisture 58.51%; solids 41.49%; ether extract (chiefly fat) 5.01%; ash 0.94%; and nitrogen 5.61% calculated as protein 35.06%. The figures compare favorably with those for beef.

Matill, at the California Agricultural Experiment Station carried out experiments to determine the digestibility of whale meat, comparing it with beef. He concluded that whale meat is as easily digested as any other meat. Raw whale meat was not so completely digested at the end of 2.5 hours as raw beef, but more completely digested than the beef in 4 hours. In the cooked condition, it was somewhat more quickly and completely digested than beef.

Drummond[2, 3] has found whale oil to be rich in the fat-soluble vitamins. This vitamin content should be an important factor in the introduction of this novel food into the dietary of Americans.

Hardened (hydrogenated) whale oil has been introduced as a lard substitute. Unfortunately this hydrogenation[2] destroys the fat-soluble vitamins and therefore such fat cannot have any advantage over vegetable fats in this regard.

Okuda, Okinoto and Yada[4] have hydrolyzed whale muscle and shown that it is not deficient in any of the more important amino acids. Their results are given in Table 85.

Pickled Whaletails.—In Japan, the tail of the whale is preserved by salting in brine and afterwards eaten. In recent years considerable quantities of whale tails have been salted at the stations on our Pacific Coast and exported to Japan.

Canning.—Canned whale meat is preferred to the fresh meat by many as the processing changes its flavor to a considerable extent. The canning

[2] *J. Physiol., 52* (1918), 95-109.
[3] *J. Physiol., 52* (1919), 328-346.
[4] *J. Coll. Agr. Imp. Univ. Tokyo, 7* (1919), 29-37.

TABLE 85

CLEAVAGE PRODUCTS, IN 100 G. OF ASH AND MOISTURE FREE MUSCLE PROTEINS

Glycocoll	0.00
Alanine	4.66
Valine	6.25
Leucine	3.54
Proline	1.51
Phenylalanine	2.59
Aspartic acid	1.47
Glutamic acid	3.28
Serine	0.49
Tyrosine	2.40
Arginine	6.48
Histidine	3.44
Lysine	9.48
Ammonia	0.91
Tryptophan	Present

industry is located chiefly in Japan and New Zealand but some also has been canned on the Pacific Coast of the United States.

The meat is stripped off the carcass, after removal of the blubber, and is held in mild pickle for about 36 hours to draw out the blood and give the meat the desired flavor. It is then cut to proper size to pack in 1 pound tall cans, which are filled mechanically, exhausted 30 minutes at 212° F. and, after sealing, are processed for 80 minutes at 220°. The canned meat has no fishy flavor and very closely resembles boiled beef.

Whale Oil.

Conversion of Blubber into Oil.—Formerly, when whaling was a deep sea industry, the blubber was stripped from the whale, hauled aboard and "tried out" on board ship. The minced blubber was merely heated over the fire in kettles ranging in capacity from 120 to 200 gallons until the heat had freed the oil and all of the water contained in the blubber had boiled out. The residue, called scrap, was drained of oil and then used as fuel for heating more blubber.

With the advent of the harpoon-gun and the speedy steam whalers, shore stations were erected in the vicinity of the whaling grounds to which the whales were towed. At these shore stations, whales may be converted into oil, scrap and meal much more economically, as none of the whale need be discarded.

Heating in open kettles over a fire produces oil of dark color and bad odor. Consequently, at the shore stations, the minced blubber is conveyed to large open vats where the oil is extracted by direct steam. After steaming, the residue is pressed usually in hydraulic presses, when more oil of somewhat lower quality is obtained. The main body of the oil is separated from water in large settling tanks after which it is barreled for shipment.

Refining.—Steamed whale oil is usually of excellent quality and for many purposes does not need refining.

In refining, the oil is heated in tanks by means of steam coils until all moisture is expelled. After heating from six to ten hours the oil is allowed to settle and partly cool, during which process the solid impurities settle out. The purified oil is then drawn from the top of the tank into barrels and casks.

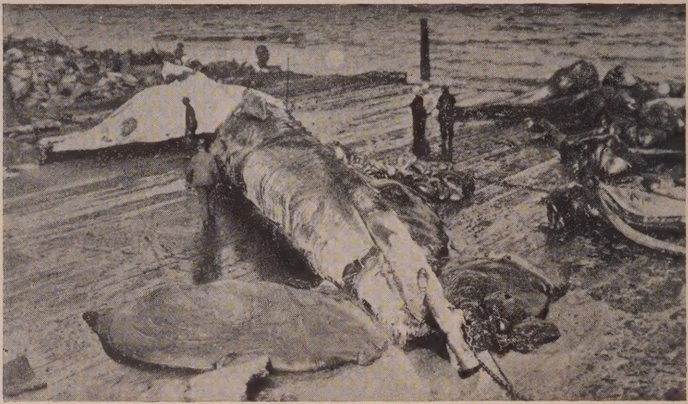

Photo by E. C. Johnston.

Fig. 230.—The flensed carcass.

The oil is then chilled. In cold weather, this is done by placing the barrels out of doors. At other times, this is accomplished by artificial refrigeration. The congealed mass is usually dumped on wooden strainers. After the liquid oil has drained off, the residue is placed in

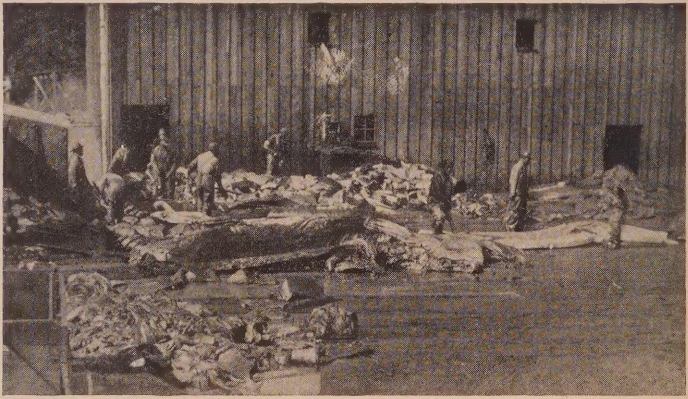

Photo by E. C. Johnston.

Fig. 231.—Baleen and blubber obtained from a whale.

canvas or hemp bags holding from 2 to 4 gallons each and subjected to great pressure. The first oil from the press congeals at 36 to 40° and is called "winter whale oil." The foots or stearin that remain in the bags average one-tenth the original bulk of the oil and are usually white.

Some oil is bleached by treatment with caustic soda or soda ash, or by exposing in shallow vats to the action of sunlight, or by filtration through fuller's earth.

Composition and Properties.

Whale oil resembles the slow drying fish and fish liver oils in many respects. It is composed chiefly of a mixture of the glycerides of the unsaturated and saturated fatty acids. Comparatively little is known concerning the chemical composition of the whale oil fatty acids. Tsujimoto found that upon bromination of the fatty acids, obtained from a sample of whale oil (from *Rachianectes glauca*), 27.81 per cent of ether-insoluble brominated fatty acids were obtained. He proved that these highly unsaturated fatty acids consisted chiefly of clupanodonic acid which is also found in fish and fish liver oils.

The iodine value of a given specimen of oil depends to a large extent upon the amount of "stearine" left in the oil, since the "stearine" consists chiefly of palmitin, a saturated fatty acid. The deposited stearine has an iodine value of about 40. The amount of unsaponifiable matter, in commercial whale oil varies from about 0.65 per cent to 3.72 per cent.

TABLE 86

Characteristics of Various Brands of Whale Oil

	Specific Gravity at 15° C.	Acid Value	Saponification Value	Iodine Value	Unsaponifiable
Antarctic right whale oil (America)	0.9257	0.56	183.1	136.0	1.46
Whale oil No. 1, unrefined (Finmarken)	0.9181	0.86	188.6	104.0	2.36
Refined (Glasgow)	0.9214	1.4	184.7	113.2	2.33
Arctic whale oil, refined (America)	0.9234	1.9	185.0	117.4	2.11
Crude white whale oil (America)	0.9222	2.5	183.9	127.4	1.37
Whale oil No. 2, unrefined (Finmarken)	0.9182	3.6	188.3	.....	3.3
Yellow whale oil, refined (Glascow)	0.9232	10.6	185.9	110.0	1.89
Whale oil No. 3, refined (Finmarken)	0.9162	26.5	185.7	96.0	2.42
Brown whale oil, refined (Glasgow)	0.9272	37.2	160.0	125.3	3.22
Whale oil No. 4, unrefined (Finmarken)	0.9205	58.1	182.1	89.0	3.4
Dark whale oil, refined (Glasgow)	0.9170	98.5	178.3	103.1	3.03

As a rule the lower the quality of the oil, the higher the percentage of unsaponifiable matter. The characteristics of a number of samples of whale oil are presented in Table 86.

Use.

Prior to the discovery of the process of obtaining kerosene by the distillation of petroleum, whale oil was extensively burned for illumination purposes. Today very little is burned, as many other superior illuminants have been discovered. Large quantities are hardened and deodorized by hydrogenation. Hardened whale oil is extensively used in the manufacture of candles, soap and lard substitutes. While hydrogenated whale oil is more nearly colorless and odorless than most hardened fish oils, it is inferior to the latter for use in the preparation of soaps, as such soaps do not possess the best lathering properties. Hydrogenated fish and whale oils are marketed in large quantities in Germany under various trade names as "talgit," etc.

The lower qualities of whale oil are employed in the currying of leather, as a lubricant, for tempering steel, as a "batching oil" for jute, etc.

Sperm Oil.

Source.—Sperm oil, spermaceti and ambergris are obtained only from the sperm whale. Formerly sperm oil was worth about twice the value of whale oil and so sperm whales were hunted extensively. These whales are very scarce now so that comparatively few whalers specialize in their capture. The few vessels which continue deep sea whaling from New Bedford obtained 152,986 gallons of sperm oil in 1922. The California whaling stations prepared 5,050 gallons and the station at Bay City, Washington, obtained 34,750 gallons of this oil in the same year.

The New Bedford whalers continue the "trying-out" of the blubber on shipboard. The body blubber and the head matter are heated separately since the oil produced from the head, because of its higher spermaceti content, is worth a little more than the body oil. On shipboard, the matter from the case in the head of the sperm whale is worked over by hand to remove the membranous tissue before being heated, as this tissue decomposes and darkens the oil during the trying-out process.

At the shore stations, where the oil is rendered by steam the separation of the membranous tissue of the case matter is unnecessary as steaming does not decompose it.

The rendering of the oil at shore stations is carried out in the manner described under whale oil.

Refining.—When the crude sperm oils arrive at the refineries they are usually mixed in their natural proportions, viz., one-third head oil and two-thirds body oil and treated together. The chief operation of refining is that of the separation of the spermaceti from the sperm oil, which is effected by prolonged refrigeration and subsequent pressing of the partially solidified mass. The crude sperm oil is allowed to stand in refrigerating chambers or out of doors from 10 to 14 days at a temperature of 0° C. (32° F.). The oil is then separated from the crude spermaceti by pressure in an hydraulic press. The clear oil, thus obtained, is known as "winter sperm oil"; according to the usual commercial standards this grade must not congeal at 38° F. Usually the amount of winter sperm oil obtained is about 75 per cent of the weight of the crude oil. This oil is bleached, usually by filtration through fuller's earth before it is marketed.

The residue from the pressing of the winter sperm oil is again pressed at a higher temperature (50°-60° F.); the oil obtained is called "spring sperm oil" and solidifies at 50° to 60° F. About 9 per cent of the total crude sperm oil is obtained as "spring sperm oil."

The press cakes are stored for several days in rooms about 80° F. After trimming they are again pressed, whereby a third grade of oil "taut-pressed oil" is produced, which solidifies at a temperature of 90° to 95° F. A relatively small amount (about 5 per cent) of this oil is obtained. The residue in the press cloths is crude spermaceti of a brown color and constitutes from 10 to 12 per cent of the crude sperm oil.

Composition and Properties.—Sperm oil differs from fish, fish liver and whale oils in consisting chiefly of waxes and not of fats. Waxes are compound esters of fatty acids and monovalent alcohols. Upon hydrolysis, sperm oil yields from 60 to 65 per cent of fatty acids and from 35 to 40 per cent of monovalent aliphatic alcohols. Since the liquid fats contain about 95 per cent of fatty acids, this characteristic serves to distinguish the liquid waxes from all fatty oils. The specific gravity of these waxes is much lower than that of whale oil and other marine animal oils.

Sperm oil absorbs very little oxygen from the atmosphere. Its viscosity is not influenced by variations in temperature to as great a degree as fatty oils. Because of these properties it is a valuable oil for many lubrication purposes.

As yet, but little is known concerning the nature of the fatty acids occurring in the liquid waxes. Fendler hydrolyzed a sample of sperm oil, still containing spermaceti, obtaining 14.22 per cent of solid and 85.78 per cent of liquid fatty acids. The solid acids melted at 32.2° C. and had a neutralization value of 242.5 (mg. KOH). Fendler attempted to separate the liquid fatty acids by fractional distillation under reduced pressure, obtaining the results given in Table 87. An examination of these data indicates that only a partial separation was effected and therefore definite results were not obtained.

Some observers have reported the presence of glycerol in hydrolyzed sperm oils. Fendler[5] found 1.32 per cent of glycerol in a genuine sperm oil. If these results are correct sperm oils contain small amounts of fats.

Upon bromination of the sperm oil fatty acids from 1.1 to 2.3 per cent of ether-insoluble bromides are obtained. This indicates that these oils contain small amounts of highly unsaturated fatty acids resembling clupanodonic acid.

As yet the exact nature of the alcohols of the waxes of sperm oil is unknown. Neither the fractional distillation of the alcohols themselves or of their acetates has given any definite information beyond proving that neither dodecatyl nor pentadecyl alcohol is present, and that the sperm oil alcohols belong for the most part, if not wholly to the ethylene series.

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[5] *Chem. Zeit.*, *29* (1905), 555.

TABLE 87

Yield Upon Fractional Distillation of the Liquid Fatty Acids from Sperm Oil

Fraction No.	Boiling Point ° C.	Pressure (mm.)	Approximate Yield (c.c. from 100 c.c.)	Iodine Value	Neutralization Value	Mean Molecular Weight
1	165-185	25	8	48.5	274.8	204.4
2	185-200	"	30	75.3	256.5	218.9
3	200-210	"	10	87.7	241.7	232.3
4	210-220	"	10	92.0	230.4	243.8
5	220-225	"	10	90.0	223.4	251.4
6	225-235	"	5	90.8	218.9	256.6
7	235-250	"	5	78.3	213.7	262.8
8	250-260	"	4	91.6	205.7	273.0
9	260-265	"	10	89.3	195.4	287.4

The chemical characteristics of 6 samples of sperm oil as determined by Dunlop are given in Table 88.

Uses.—Sperm oil is largely used as a lubricating oil for spindles and other light machinery, because of its slight tendency to "gum" and on account of slight decrease in viscosity with increase in temperature.

TABLE 88

Characteristics of Sperm Oil

	Cold Test ° C.	Sp. Gr. at 15.5° C.	Wax Alcohols, etc. Per Cent	Iodine Value (Wijs)	Saponification Value	Butyrorefractometer "Degrees" at 25° C.	Free Acid as Oleic Acid Per Cent
Sperm oil from "head matter"..	9.5	.8779	42.28	76.30	140.2	49.7	4.60
Sperm oil from "body matter"..	8.5	.8772	42.14	92.85	124.8	54.8	1.42
Sperm oil from "head matter"..	7	.880	41.16	70.35	144.4	50.0	1.39
Sperm oil from "body matter"..	7	.8757	44.30	87.90	122.0	54.6	1.07
Southern sperm oil	...	.8791	41.16	84.35	129.7	54.6	1.16
Southern sperm oil	...	.8798	39.20	84.37	129.0	....	2.53

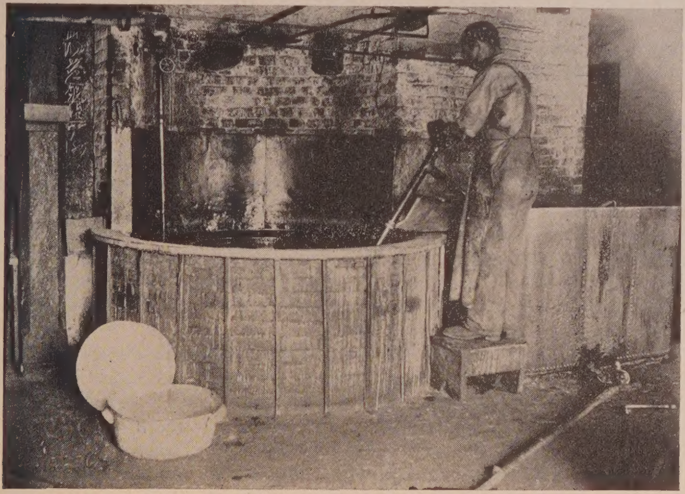
By-Products—Spermaceti.

Refining.—The mode of separating crude spermaceti from sperm oil has been described on page 638. Crude sperm oil yields about 11 per cent of spermaceti.

Crude spermaceti is refined by melting and boiling for two or three hours with dilute caustic soda solution (2.5%). The clarified oil is washed with water until it is free from alkali and then drawn off into flat tin moulds where it is permitted to crystallize. The cakes are pulverized and then the wax is pressed in bags in a hydraulic press, first in the cold and then in the hot.

Properties and Composition.—Refined spermaceti is a white, lustrous, translucent crystalline substance; it is tasteless and odorless and so brittle that it can be rubbed into a powder with the fingers. One part of the wax is soluble in forty parts of boiling alcohol. On cooling, the bulk, consisting chiefly of cetin, separates in a crystalline form.

Spermaceti consists chiefly of cetin (cetyl palmitate). Pure cetin may be obtained by repeated recrystallization from alcohol. Commercial spermaceti has iodine values varying from 3 to 10, depending upon the care taken to free it from sperm oil which is always present in small amounts. Lewkowitsch[6] examined a commercial sample of the saponification value 122.3 having the acetyl value 2.63 and concluded that this indicates the presence of a small amount of free alcohols.



Courtesy Bureau of Fisheries.

FIG. 232.—Refining spermaceti.

Spermaceti contains small amounts of free fatty acids varying from 0.09 to 1.35 in acid value. Higher acid values than the latter figure indicate the adulteration of the spermaceti with stearic acid or beeswax.

Adulteration of spermaceti is usually easily detected, as the presence of foreign substances causes it to lose its physical characteristics as color, transparency and crystalline structure. A high iodine value usually indicates the presence of tallow.

The chemical and physical characteristics of spermaceti are as follows: Specific gravity at 15° C. 0.905-0.960; melting point 41-46° C.; saponification value 120.6-134.6 (mgs. KOH); iodine value 3.5-9.3; alcohols 49.0-54.27%; fatty acids 49.78-53.45%.

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[6] *Analyst, 24* (1899), 321.

Uses.—Spermaceti is widely used in the manufacture of certain cosmetics, especially face creams of the "cold cream" variety.

Other uses are for the preparation of cerates and for the manufacture of wax candles.

Arctic Sperm Oil.

This oil is obtained chiefly from the bottlenose whale, *Hyperoodon rostratus* and *H. diodon* (*bidens*). Arctic sperm oil is rendered and refined in the same manner as sperm oil. The oils resemble each other so that it is nearly impossible to distinguish them by a chemical analysis. Physically these oils are readily distinguished by their taste. Arctic sperm oil gums much more quickly than sperm oil, therefore it sells for a lower price.

Since the properties and composition of this oil resembles so closely those of sperm oil, they will not be considered in detail.

Scrap.

Manufacture.—The flesh of the whale is cut into small pieces and placed in a pressure cooker where it is cooked under about forty pounds steam for about ten hours. The water and oil are drawn off and separated. The residue is pressed, usually in hydraulic presses, and dried. The latter operation is usually carried out in horizontal rotary hot-air driers similar to those employed in the drying of menhaden scrap (see page 458).

The dried scrap is ground finely, the degree of fineness depending upon the use for which it is intended.

The tongue and kidney fat are cooked with the blubber, but the remainder of the viscera are cooked under steam pressure in the same way as the meat is cooked. Oil is obtained which is of lower quality than that produced from blubber. The cooked viscera are pressed and dried and mixed with the scrap obtained from the flesh.

The bones are spongy and contain much oil. Therefore after being cut up, they are also cooked under steam pressure. The bone oil obtained is also of second quality. The steamed bones are dried, usually in a rotary hot air drier. The dried bones are ground into bone meal.

Composition and Use.—The proximate composition of samples of whale meal and whale bone meal as given by Turrentine [7] are given below:

	Nitrogen	Phosphoric acid (P_2O_5)	Moisture	Oils
Whale meal	11.59%	0.94%	5.41%	12.80%
Whale bone meal	3.01	26.08	2.53	Trace

Whale meal possesses a high protein content, and, as whale flesh is readily digestible (see page 634), makes an excellent feed for use where a concentrated protein foodstuff is desired.

Whale scrap is also largely used as a fertilizer. Scrap with a low content of fat makes the most desirable manure.

[7] *U. S. Dept. Agr. Bull. 150* (1915).

Whale bone meal of low fat content has a high phosphoric acid (P_2O_5) content and is extensively used as a fertilizer. Unit for unit it may be considered to be the equivalent of packing house bone meals.

Whale scrap sold for fertilizer purposes usually contains about 30 per cent of bone meal mixed with it. This increases its phosphoric acid content and makes it more desirable as a manure.

Whalebone.

Baleen or whalebone is not the bone of whales as might be guessed from its name, but is the strainer-like appendage consisting of several hundred horny elastic slabs or plates which are attached to each side of the upper jaw of the whalebone whales. The following commercially important whales yield whalebone: Greenland right or bowhead, Nordkaper or Biscay right, southern right whale, humpback, blue, finback, sei, bottlenosed and the California gray whale. Of these, the first three yield the best qualities of whalebone; most of the others yielding baleen of little value. The whalebone obtaind from the Greenland right whale is the best obtainable, having a length up to 15 feet. A single whale of this species has been known to yield as much as 3,100 pounds of whalebone. The baleen of the finback whale is very short, seldom exceeding 4 feet in length. The fibres are much coarser than in the baleen of the right whales; this variety is much less in demand, selling for about one-tenth the price of that of the bowhead whale.

Whalebone is easily extracted by pushing a cutting spade along the groove between the gum and jaw bone. The baleen is then separated with spades and axes into pieces of convenient size, containing from 3 to 6 slabs each. At the same time, all of the meat and blubber and most of the gum is removed. The slabs are then carefully washed in salt water and thoroughly dried.

The economic value of whalebone is due to its lightness, elasticity and flexibility, and to its property of permanently retaining any shape that may be given it when it is heated and then cooled under pressure.

New York City is the center of the American whalebone cutting industry. Most of the whalebone taken by European whalers is shipped to Paris where it is prepared.

After the hair or fringe covering the smaller end of the slabs has been cut away, the slabs are soaked in warm water for a week or two and are then steamed for 40 to 60 minutes.[8] The slabs are then cut up into the desired pieces by draw knives adjustable to any depth.

The most important use of whalebone is in the manufacture of corset stays. Much is also cut into fine threads and woven into silken fabrics for stiffening purposes. Being very strong and flexible, it is used for making the better grade of whips.

The Japanese are very clever at working whalebone and utilize even the short, lower grades such as that obtained from the finback whale. They make cigar and cigarette cases, sandals and many other beautiful things from it.

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[8] Stevenson, C. H., *Bureau Fisheries Doc.* 626 (1907).

Miscellaneous Products.

Ambergris.—Ambergris is the most valuable product obtained from whales and sometimes is worth its weight in gold. In 1922, the total production in the United States was 44 pounds, valued at $11,000, which was landed at New Bedford.

Ambergris is a biliary concretion from the intestines of the sperm whale and is found sometimes in the animal itself, but more often floating upon the sea or in the sand on the seacoast. It occurs in lumps varying from a few ounces to 200 pounds. It is of a solid waxy nature, mottled dull gray to black, and possesses a peculiar earthy odor. The specific gravity of ambergris varies from 0.780 to 0.926. Its melting point has been reported as varying from 60° to 65° C. It is soluble in ether and in the volatile and fixed oils.

The principal constituent of ambergris is ambrein, a substance melting between 82° and 86° C., which Riban[9] found to possess the formula $C_{23}H_{40}O_2$. Cole[10] has found that a microscopical examination is the most accurate means of identifying the substance, as true ambergris contains many fragments of the chitinous part of the internal shell of cuttlefish which serves as food for this whale.

Ambergris has been used for centuries in certain sacramental rites. The Chinese and Moros also use it medicinally.

Its principal use in America and Europe is in fine perfumes, to which it is added as a fixative.

The value of ambergris depends largely upon its scarcity at the time.

Epinephrin.—Weidlein[11] has shown that the suprarenal glands of finback whale contain about 0.2 per cent of epinephrin or adrenaline. However there has been no attempt to utilize the glands commercially.

Leather.—The utilization of the hide and the intestines of the whale as leather is discussed on page 501 in Chapter 26.

Glue.—The solution separated from the whale oil in the vats where the blubber is steamed contains much glue formed by the solution of the hide. This is evaporated to a more concentrated solution and allowed to jell. The glue jelly is cut into thin strips and dried on chicken wire frames.

Dolphins and Porpoises.

The fishery for these cetaceans is of minor importance. Porpoises are caught in considerable numbers on the coast at Cape Hatteras at certain times but the fishery has never attained importance. Porpoises, dolphins and brown-fish are occasionally taken by the New Bedford sperm whalers. At times, considerable numbers of black-fish are captured on the shore of Cape Cod. A regular fishery for porpoises exists in Finmark from September to March where much of the flesh is eaten; what is not consumed is salted and exported.

On the North Carolina coast, the porpoises are captured in large haul seines which are landed upon the beach. The seine used is often 1,000 yards or more long, 25 meshes deep of 8-inch barmesh.

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[9] *Compt. Rend., 154* (1912), 1729-1732; also *Bull. Soc. Chim. IV, 11* (1912), 754-757.

[10] *Philippine J. Sci., 20* (1922), 105-9.

[11] *J. Ind. Eng. Chem., 4* (1912), 636-645.

Little use is made of the porpoises in North Carolina except for the preparation of oil. The blubber from the body is kept separate from that obtained from the jaw as the latter is the source of the valuable jaw-oil.

The jaw-oil is prepared by cooking with water the fat obtained from a large depression on the inner side of the posterior part of the lower jaw. The average quantity of jaw-oil obtained from each porpoise is not much more than half a pint.

The body blubber is minced and either heated in a try-pot over a fire or is cooked with water. The yield of oil is about two gallons per animal, although this varies greatly with the fatness of the various individuals.

In refining, the porpoise jaw-oil is first heated for some time and is then allowed to stand for a long period (usually one or two years). Then it is chilled in thin layers to a temperature below 0° F. The chilled oil is strained through a fine cloth to remove the congealed substances. The product does not gum and will withstand the coldest climate without congealing.

Characteristics and Uses of Oil.

Dolphin Body Oil.—Dolphin oil is of a pale yellow color. Upon standing in the cold it deposits spermaceti. It contains considerable amounts of volatile fatty acids; its Reichert value varies from 5 to 45 (c.c. N/10 KOH), depending upon the species of dolphin. Tsujimoto[12] examined dolphin oils prepared from *Delphinus longivostris* and determined the characteristics given in Table 89.

Dolphin Jaw-Oil.—The jaw-oils obtained from dolphins, porpoises and brown-fish are characterized by their extraordinarily high amount of glycerides of volatile fatty acids that they contain. Moore examined a sample of oil having a Reichert value of 65.92 (c.c. N/10 KOH). The jaw-oil from *Delphinus longivostris* contains much larger amounts of volatile fatty acids (see Table 89).

TABLE 89

CHARACTERISTICS OF DOLPHIN OIL

	Oil from Head	Oil from Body		Refined Head Oil
		Boiling Process	Roasting Process	
Specific gravity	0.9249	0.9286	0.9307	0.9259
Saponification value	279.78	217.22	230.35	277.70
Iodine value	24.48	125.25	114.35	25.67
Reichert-Meissl value	112.31	30.40	44.39	....
Refractive index at 20°	1.4524	1.4717	1.4695	1.4517
Butyro-refractometer	40.0	69.0	65.5	39.0
Acid value	2.30	11.90	3.97	0.26
Octobromides of fatty acids, per cent	....	24.75	....	....

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[12] *Chem. Rev. Fett. Harz. Ind., 20* (1913), 70-73.

The jaw-oil is one of the most valuable of oils; it is used chiefly for the lubrication of fine machinery such as watches and typewriters.

Porpoise Body Oil.—Porpoise oil resembles dolphin oil in its composition and properties. Bull reported the following results of an examination of a commercial sample of the oil: Specific gravity (at 15° C.) 0.9258; saponification value (mgs. KOH) 195; iodine value (%) 119.4.

Porpoise Jaw-Oil.—Porpoise jaw-oil is similar to dolphin jaw-oil, in composition and properties and is therefore used for the same purposes, i.e., lubrication. It is soluble in alcohol at 70° C. and therefore it is possible to separate it from the body oil which is insoluble under similar conditions. Moore reports the following characteristics: Saponification value (mgs. KOH) 253.7; iodine value (%) 49.6; Reichert value (c.c. N/10 KOH) 47.77.

Brown-Fish Oil.—The body oil of *Phocæna communis* has a pale yellow color. Like porpoise and dolphin oils it is characterized by a high proportion of the glycerides of the volatile fatty acids. Its characteristics are approximately the following:

Specific gravity (at 15° C.)	0.933
Saponification value (Mgs. KOH)	225
Iodine value (%)	111
Reichert-Meissl value	42

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Chapter 35.

Seals and Walruses.

By WARD T. BOWER * and E. C. JOHNSTON.†

History of Fur Sealing.

Information in regard to the early history of the fur-seal industry is fragmentary, but great herds of these animals had been discovered in Antarctic waters and also in the North Pacific by about the middle of the eighteenth century, and at the beginning of the following century they were being exploited extensively. The Russians in early years had practically a monopoly of operations in the northern waters, while chiefly American and English vessels, with a few Russian, were taking great numbers of seals from islands widely scattered over the Southern Hemisphere.

Sealing in the Southern Hemisphere.

Probably the herds of the Antarctic were at one time far larger than the northern ones, but they have long ceased to be of commercial importance. No estimate can be placed on the total number of skins taken but there were many millions. In recent years a few hundred skins have been secured off the African Coast, in the vicinity of Cape Horn, and off the coasts of Peru and Ecuador, but probably the most important herd in the Southern Hemisphere is now that on Lobos Island, in the mouth of the La Plata River, which has been protected for a number of years by the Government of Uruguay. In the last few years an average of about three thousand skins has been taken there annually.

An extensive and interesting account of the operations of American sealers is given by A. Howard Clark, "The Antarctic Fur-Seal and Sea-Elephant Industry," in The Fisheries and Fishery Industries of the United States by G. B. Goode and Associates, 1887. With reference to the distribution of seals in southern oceans, the following is quoted from the article mentioned:

> At the beginning of the nineteenth century the fur seal was in great abundance on nearly all the islands off the west coast of South America, from Cape Horn to the Equator, and was taken in great numbers from the islands of Juan Fernandez and Mas-á-Fuera, from St. Felix and St. Ambrose Islands, the Galapagos, and numerous other islands off that coast. It was captured also in 1820 to 1825 at the South Shetlands in great quantities. The islands of the Falkland Group, the South Georgia Islands, the Sandwich Group, and other places south and east of South America, were annually visited by fleets of vessels. Off the west coast of Africa

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they were taken as late as 1835 to 1840, when they became almost extinct. At Desolation or Kerguelen Land, at the Aucklands, the Antipodes, the Crozet Group, and everywhere on islands in those cold waters, the fur seal was found and captured; but so eager were the sealers for gain that no regard was paid to the danger of exterminating the animals by an indiscriminate slaughter of young and old seals, so that it was but a comparatively short time before once famous sealing grounds could no longer be visited with profit to the hunter.

Mr. Clark also states that prior to 1815 about the only market for fur-seal skins was China and that they were then dressed usually in the manner of hair seals for the hide, which was used in the manufacture of trunks, valises, etc., the fur being cut off clean and thrown away as useless. The skins were also invariably dried at first, but after about 1815 they were practically all cured by salting. The market was later transferred to London and an excellent method developed for the dressing and dyeing of the fur.

Northern Seal Herds.

The early history of the northern herds was similar in its story of exploitation and depletion. The herd on the Commander Islands became known in 1741, that of the Pribilofs in 1786, and those of Robben Island and the Kuriles about the middle of the nineteenth century. Great numbers of skins were taken for many years and the herds became depleted, but through restrictions on killing from time to time the herds were allowed to recuperate. The Russian method of handling the sealing industry was through the granting of leases to companies which established settlements on the islands to which the herds resorted, and carried on sealing operations in a more or less systematized manner.

Russian and Japanese Herds.—Depredations by raiding expeditions and the method of killing seals at sea were very destructive to the herds on the Commander Islands and Robben Island, and that on the Kuriles was completely exterminated. Dr. Leonhard Stejneger, who paid extended visits to the Commander Islands and Robben Island and made careful reports on the herds,[1] has computed that at the time of his last visit in 1922 the Commander Islands herd comprised not over eighteen thousand animals and the Robben Island herd, which has been under the jurisdiction of Japan since 1905, contained about twenty thousand animals. However, Dr. Stejneger reports that the herd on Robben Island is now well managed by the Japanese and is showing a remarkable increase. The take in recent years on these islands is shown in the table on page 650.

Pribilof Islands.—The only great seal herd of the world now is the one which still resorts to the Pribilof Islands. During the eighty years of Russian control preceding the purchase of Alaska by the United States probably 3,500,000 skins were taken from these islands, and the number of animals in the herd at the time of the transfer has been variously estimated to have been from 2,000,000 to 4,000,000. When it is remembered that all the other herds of the world have been either greatly depleted or totally exterminated, the practical efforts of the Russians to

[1] Asiatic Fur-Seal Islands and Fur-Seal Industries. In Report of Fur-Seal Investigations, 1896-97, by David Starr Jordan and Associates. Washington, 1897.

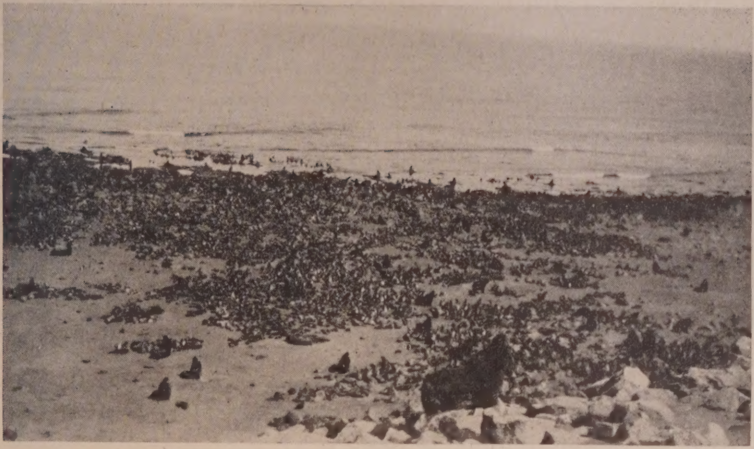


FIG. 233.—Section of fur-seal rookery, Pribilof Islands, Alaska.

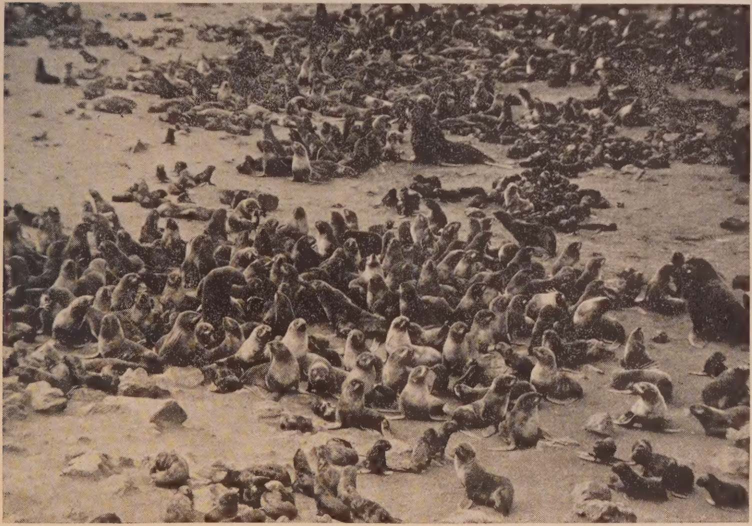


FIG. 234.—Large fur-seal harem, Pribilof Islands, Alaska.

Take of Sealskins on Commander Islands and Robben Island from 1913 to 1922

Year	Number of Skins	
	Commander Islands	Robben Island
1913	...	547
1914	...	537
1915	...	571
1916	...	...
1917	810	...
1918	302	550
1919	175	555
1920	479	554
1921	52	550
1922	500 *	660

* Approximate.

conserve the Pribilof herd are appreciated. For a period of forty years following the purchase of Alaska the sealing privileges on the Pribilof Islands were granted to lessee companies. Under the first lease 1,977,377 skins were taken and under the second 342,651 skins. On the expiration of this second lease of the islands in 1910, the Government took over the management of the seal industry which is now carried on by the Bureau of Fisheries of the Department of Commerce.

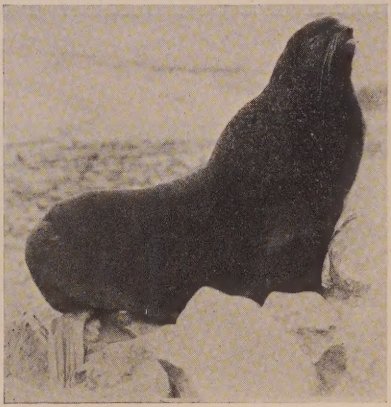


Fig. 235.—Old fur-seal bull, Pribilof Islands, Alaska.

Development of Pelagic Sealing.

For many years the Indians of the coast of Washington and British Columbia had been accustomed to go out in canoes and spear fur seals as the herd passed northward in the spring on its annual return to the Pribilof Islands. The first pelagic sealing conducted from vessels began along this coast between 1871 and 1878. After 1880 the industry developed rapidly and vessels from a number of countries took part in it, the scene of operations extending from the Farallon Islands, off the coast of California, along the coast of Alaska, in Bering Sea, and also along the coast of Japan and in the vicinity of the Commander Islands.

The peak of the industry probably was reached in 1895, in which year 102 vessels of the Canadian, Japanese, and American sealing fleets secured a total of 92,437 skins in North Pacific waters. From the best data available it appears that approximately 974,640 skins were taken from the Pribilof herd in pelagic operations from 1868 to 1911, inclusive. The number of skins taken in pelagic operations is not indicative of the actual effect on the seal herd, since the real destruction wrought is apparent only in future years. On account of the seal's habits and the methods of pelagic sealers, a very large percentage of the take was females and the death of a cow included the death of at least one pup. Also from three to five seals were killed for every one retrieved. Had not this industry been curbed in time it would have exterminated the fur seal of the north within a very few years.

After protracted negotiations the Governments of Great Britain, Japan, Russia and the United States entered into an agreement by the Fur-Seal Convention of July 7, 1911, whereby pelagic sealing was prohibited. The Pribilof herd was at that time reduced to about 132,000 animals. Certain aborigines on the Pacific Coast are still permitted to kill seals under regulations prescribed by the treaty. In the period from 1912 to 1922, inclusive, British Columbia Indians have taken 6,307 skins and Indians of the United States and Alaska have taken 5,729, a total of 12,036 skins secured in pelagic sealing operations since the treaty was made.

Species of Fur Seals.

Two grand divisions are made in the classification of fur seals, those of the Northern Hemisphere bearing the generic name *Callorhinus,* and of the Southern Hemisphere *Arctocephalus.* A number of species are recognized under each of these. The location where each species is found and a brief description follows:

Callorhinus alascanus, Jordan and Clark. Pribilof Islands. Head comparatively stout and broad with thick neck; contrasts between coloration of sides and belly lacking; claws of fore-flippers undeveloped; fur of superior quality.

Callorhinus ursinus, Linn. Commander Islands. Head and neck slender; belly usually sharply paler than the back; gray pup with pale patch on each side of rump; more brownish and less gray than *alascanus;* fore-flippers with 2 or 3 rudimentary claws.

Callorhinus curilensis, Jordan and Clark. Robben Island. Head broader than in *ursinus;* under fur of whitish color (rusty brown in *alascanus* and *ursinus*); quality of fur so different from either of the other species that the pelts must be treated by a separate process.

Arctocephalus townsendi, Merriam. Guadalupe and other islands off Lower California. Extinct or nearly so.

Arctocephalus philippii, Peters. Juan Fernandez Island. Mas-á-Fuera Island, probably also coasts of Chili and adjacent islands, St. Felix group and the Galapagos Archipelago. Commercially extinct but remnants of herds persisting.

Arctocephalus australis, Zimm. Southern coasts of South America from the southern border of Brazil and Chili southward; also Falkland Islands and Tierra del Fuego, and probably also the South Shetland and South Georgia Islands and the Sandwich group.

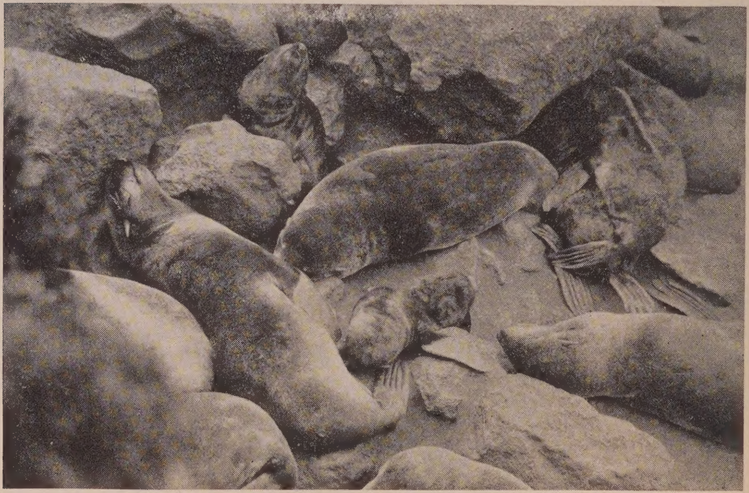


FIG. 236.—Nursing fur-seal pup and cows.

Arctocephalus delalandi, Gray. Shores and islands adjacent to west coast of South Africa north to about latitude 28° S.; also Tristan d'Acunha and Gough Islands. The government of Cape Colony has preserved and protected a colony on its west coast.

Arctocephalus gazella, Peters. Kerguelen Island, St. Paul and Amsterdam Islands and probably the Crozet and Prince Edward Islands. New Zealand has provided protection to the few animals within her jurisdiction.

Habits of Fur Seals.

The fur seals, in all parts of the world, are remarkably similar in their gregarious and polygamous habits. All species resort to particular breeding grounds or rookeries after a more or less lengthy migration at sea. As the breeding season approaches the mature males arrive first at the rookeries and take up definite stations which they persistently hold and protect. During the time they are on land, usually about 4 months, the bulls neither eat nor drink and their sleep or rest is limited to a few minutes at a time. They are sustained by the thick layer of fat or blubber which is stored up during their migrations. The cows arrive after practically all of the bulls are in position, and come ashore a short time before the young are born. They make frequent trips to sea for food which consists largely of squid and fish. But a single young or pup is born annually. A cow produces her first offspring in her third year. The younger males, until they are large and vigorous enough to secure and protect harems, do not mingle with the old bulls and cows on the breeding grounds but they come ashore at a separate place where they sleep and play. It is from this class, called bachelors, that the skins are secured on the Pribilof Islands.

Sealing Methods on Pribilof Islands.

The Pribilof Islands, in the Bering Sea, Alaska, are the most important breeding grounds of the fur seal existing in the world today. There are more fur seals on this group of islands and more skins are taken there annually than on all the other rookeries in the world combined. A staff of white employees under the Bureau of Fisheries is maintained on the islands to direct sealing operations, the actual work of killing and skinning the seals, and the salting of the skins being done by the Aleut natives of the colonies settled on the islands by the Russians. The take of skins under Government management is shown below:

1909	1,825	
Turned over to lessees to complete quota of 15,000	664	
		1,161
1910		12,964
1911		12,132
1912		3,191
1913		2,406
1914		2,735
1915		3,947
1916		6,468
1917		8,169
1918		34,890
1919		27,821
1920		26,648
1921		23,681
1922		31,156
Total		197,369

The close period imposed by the law of August 24, 1912, in which seals were killed only for native food, ended with the season of 1917. This prohibition resulted in a surplus of adult males which was reduced in the killings of 1918, 1919, and 1920, and the proper proportions restored between the various classes of animals. Each year during Government management a census of the seals in the herd has been taken, which has shown a growth in numbers from the estimate of 132,000 in 1910, to 604,962 animals as of August 10, 1922, the date to which all censuses have been computed.

Federal Protection.

These breeding grounds are afforded rigorous protection by the United States Government. No unauthorized person is permitted to land at the islands and no unauthorized vessel is permitted to call there except through stress of weather, accident or like unavoidable conditions. The number of skins taken annually is set in advance so that the needs of the herd for propagation will not be endangered thereby. Killings are confined to 3-year-old males and a breeding reserve of that class, to the number of 5,000 annually, is required by law to be set aside. The object of all these restrictions and regulations is to protect the animals from unnecessary disturbance on their breeding grounds, to prevent the taking of skins by others than the agents of the Government, and to allow the herd every opportunity to increase to its former numbers.

Killing.

Owing to the highly polygamous habits of the fur seals a very large percentage of the males may be killed without diminishing this breeding strength. Theoretically the number of young males killed by man would die from natural causes before they reached the breeding age which is in their eighth year. Killing is done on land during the breeding season. The young males or bachelors, when they come ashore, are not permitted by the breeding males to enter the actual breeding areas. From their hauling grounds they are easily driven to the killing fields which are situated at some distance from the rookeries to avoid unnecessary disturbance of the breeding seals.

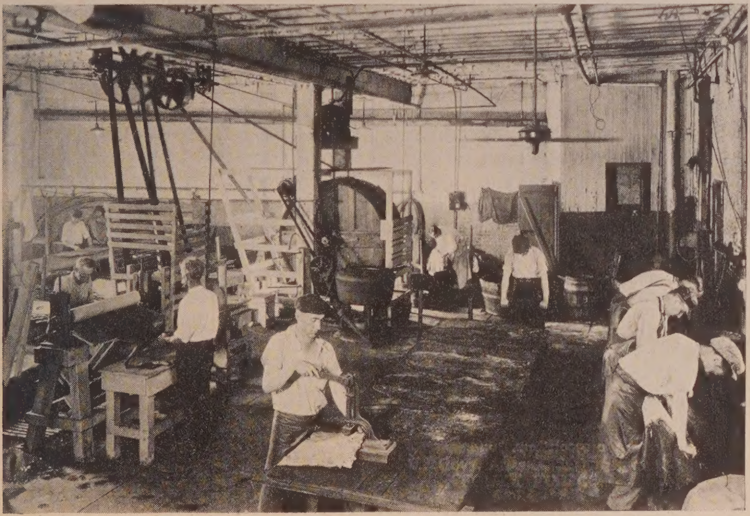
In killing the animals they are first struck on the head with a club shaped like a ball bat but about 6 feet long. The blow instantly renders them unconscious and while in this condition they are thoroughly bled so that death occurs quickly and painlessly. Before the carcasses are skinned a record is made of the length of all animals by the use of beam calipers. These measurements indicate the age of each animal killed.

Skinning.

Formerly the pelts or skins were removed by skinning with a knife in the usual manner. This frequently resulted in damaging the pelt by cutting and flaying. Experiments showed that it was possible to pull the skin off after cutting around the head and flippers and down the belly. By this method the seal's skull is pinned to the ground by a sharp iron bar and the skin pulled off from head to tail, the operation taking less than a minute. A large amount of blubber and flesh adheres to the pelt so that there would be difficulty in curing and in order to employ this new method successfully it has been necessary to make another radical change in the work done on the island. Before salting the skins, this blubber and flesh is removed.

Handling of Pelts.

As soon as the pelts have been removed they are washed in large tanks and afterward blubbered. Then they are sent to the salt house where each skin is spread out, fur side down, and covered with a thin layer of salt. Care is exercised to prevent the edges of the skin becoming folded since such a condition will cause imperfect curing of the skin at the fold. The salted skins are piled 4 to 6 feet high and are left for 10 days which is the time required to cure blubbered skins. After the skins are cured they are rolled up separately in compact bundles and packed in water-tight barrels. The pelts are shipped to St. Louis, Mo., where they are finally prepared for market as described.



Courtesy Fouke Fur Company.

Fig. 237.—Removing blubber and cleaning fur-seal skins, St. Louis, Missouri.

Disposition of Carcasses.

After the pelts have been removed from the carcasses the natives secure meat from desirable portions both for immediate and later consumption. A sufficient number of carcasses are put away on St. George Island to provide fox food for the coming winter. A by-products plant on St. Paul Island extracts the oil from the blubber removed from the skins and from as many of the seal carcasses as may be necessary to furnish the quantity of oil needed in tanning the skins. Fertilizer is made of the residue after the removal of the oil. Carcasses which are not used are left on the killing field for fox food, some of which lasts through the winter.

Fur-Seal Markets.

Although the United States has, ever since the development of a commercial sealskin dye, consumed upwards of 75 per cent of the finished sealskins, the great sealskin market was centered in London until recently, the main reason being that London was the only place that produced a successful dye. In 1915 the industry was moved to St. Louis, Mo., and as a result this city is now the center of the sealskin market. At that time a number of the best seal dressers and dyers of London were brought to St. Louis and with these men as a nucleus, a large organization devoted to this process has been developed. By intense application and research this organization has developed the finest product ever turned out. The few disadvantages found in the old product have been overcome and a strong, thin, light pelt has been produced, so that now a genuine sealskin garment weighs scarcely any more than one made of the substitute —Hudson seal, or dyed muskrat.

Classification and Grading of Pelts.

Sealskins are classified and graded according to size, quality of fur and condition of pelt, both in the raw salted condition and in the finished condition ready for making into garments. There are now six sizes, the new names being Small Medium (S.M.), Medium (M), Large (L), Extra Large (X.L.), Extra Extra Large (X.X.L.), and Wigs (W.). The fur is graded according to silkiness, denseness and length. The condition of the pelt must be carefully examined for defects which would offset any good qualities resulting from fine fur. A good raw skin should be thoroughly cured, free from all traces of taint even in spots, and the flesh side of the skin should also be free from cut marks produced by the knife in the skinning operation. The finished skins are classified according to length in inches as shown by the following schedule:

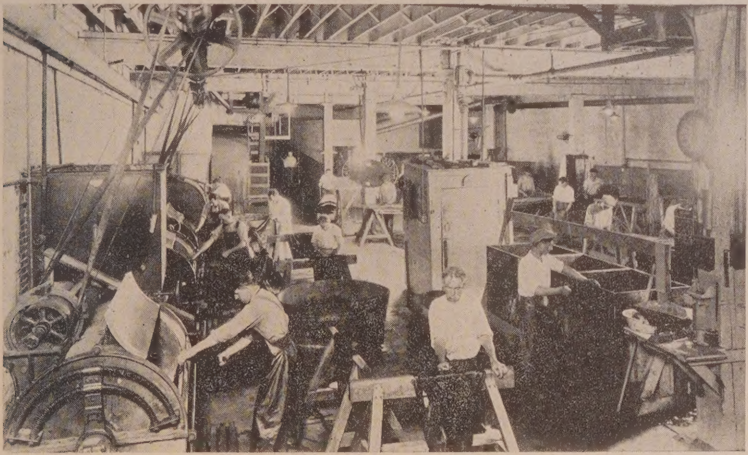
Small Medium	below 38	inches
Medium	38 to 42	"
Large	42 to 45	"
Ex. Large	45 to 48	"
Ex. Ex. Large	48 to 55	"
Wigs	Over 55	"

The classification and grading of raw sealskins is very difficult and reliable judgment in this work is obtained only after many years of practical experience, not only in the actual handling of raw pelts but also watching these same pelts through the dressing and dyeing process in order to check up and verify the original grading. There are many defects seriously affecting the finished pelt which may be partly or entirely obscured in the raw condition but show up soon after being started through the dressing and dyeing process. In previous years when the market was in London there were probably not more than half a dozen men whose opinion on the value of raw sealskins was at all dependable.

The Government sealskins are now sold at public auction in the dressed, dyed and finished condition. This renders the grading very much easier and as a result a much larger number of people are able to bid intelligently on the skins. The bidders and buyers now consist largely of dealers and manufacturers of garments, actual users of sealskins, and as they are experienced in handling and using finished seals they are perfectly capable of judging the article in this condition.

Preparation of the Fur.

The skins having been blubbered, the next process in the actual dressing is that of unhairing which consists in removing the outer guard hair, for the coat of the fur seal in its natural state consists of two distinct growths, the soft downy undergrowth of fur and the outer coarse, harsh growth of guard hair. Most fur-bearing animals have a similar coat consisting of fine fur and heavier guard hair but the difference in fineness between the two growths is greater in the fur seal than in most other furs. The operation of unhairing requires considerable experience, skill and judgment. Practically all previous handling of the skins is a preparation for this unhairing. The success of the operation depends on getting the skins in just the right condition, when the outer guard hair can be removed with comparative ease while the undergrowth of fur is retained firmly by the skin. The actual operation again resembles dehairing in the leather industry. When the skin is in the right condition the pelt is laid, fur up, over a beam and the guard hair is pushed off by a curved blunt knife. The hair is not cut or "plucked" as is the case with practically every other fur, but is drawn out by the roots. It is found that this method produces a product far superior to the usual plucking, for the follicles, after the hair is extracted, close up and leave no trace of their existence. This more than anything else tends to produce a smooth, velvety fur.



Courtesy Fouke Fur Company.

FIG. 238.—Washing fur-seal skins, St. Louis, Missouri.

After unhairing, the skins are tanned or "leathered." They are given a preliminary treatment in which a slight amount of moisture is left in the pelt. Seal oil, which as mentioned above is extracted from the seal's own blubber, is then painted on the flesh side and the skins are run in a "mill." The action of this mill is similar to the old method in which men tread on the seal-skins in their bare feet but the machine is much more effective and uniform in its action and very much more rapid. The tannage is produced entirely and solely by the action between the seal oil and the hide fibre, no so-called "chemicals" being used. This process produces a true oil tannage commonly known as chamois tannage.

During the tanning process the fur naturally becomes very greasy, and before dyeing is attempted this grease or oil must be removed. This is accomplished by running the sealskins several times with hardwood sawdust in specially constructed mills. In these mills the skins and sawdust are together kicked back and forth and the sawdust is forced down through the fur to the grain, and absorbs by capillary attraction the grease held by the fur. In between the mill runs, the dirty sawdust is shaken out of the skins by tumbling them in steel wire "cages" (similar to some methods of carpet cleaning). This allows clean, fresh sawdust to get down into the fur.

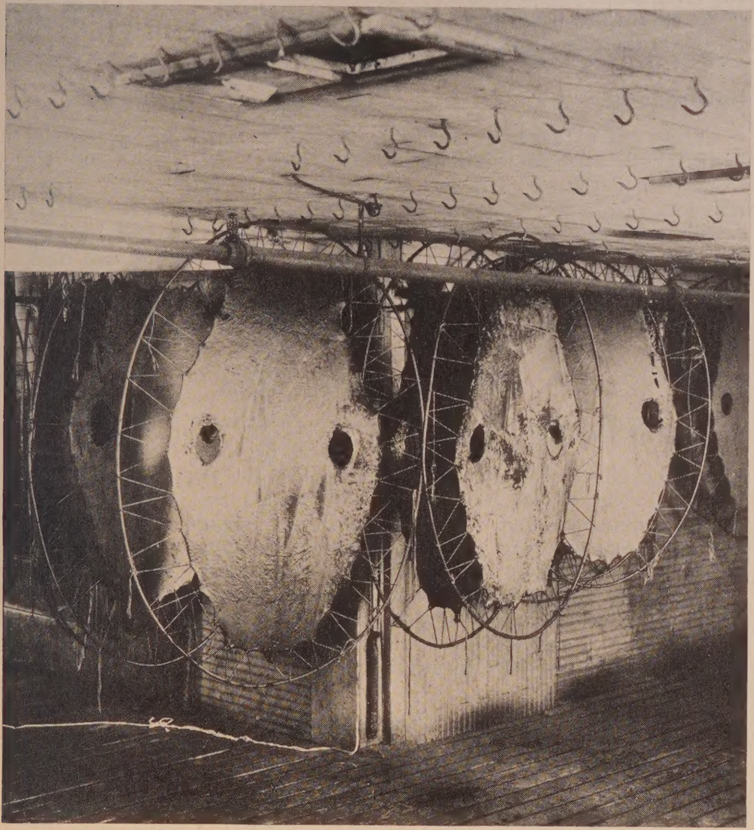
Sawdust is a very useful and necessary material in the dressing and dyeing of sealskins. It is used probably twenty-five or thirty times during the process and special kinds of dust are most suitable for each different operation. No other material that has been tried, such as cornmeal, etc., has proved as satisfactory. For sealskins and other furs, however, only the best grades of hardwood dust are suitable. Dust from soft resinous wood would spoil the furs.

The skins are then dyed. This operation requires considerable skill and experience as it is entirely done by brushing the dye on the fur and not by immersing the skins in a dye bath. The dyeing operation is divided into three main steps. In the first step the fur is given what is called "killing," really a mordant. The next operation consists in applying a vegetable black to the upper half of the fur. In the last operation the whole length of the fur from the tips to the roots is given a rich chocolate brown, also a vegetable color. It is this method that produces half brown and half black fur which has been imitated in substitutes such as Hudson seal. More than two dozen applications of dye are given to the fur.

The pelts are still too thick to be used by the furrier, and so are reduced in thickness by passing them through shaving machines, which consist of a large cylindrical drum covered with an abrasive and revolving rapidly. The surplus pelt is actually buffed off. During the dyeing process the pelt itself is not stained through with the dye, it merely picks up a surface coat of black. In the buffing operation this black surface is removed and a white or rather light yellow chamois leather is produced.

The unhairing process, described above, removes only the coarse hair which is longer than the fur. Practically every sealskin, however, has more or less of a growth of stubby hair which is shorter than the fur and must be removed in some other way. This is done after the pelt is reduced to the proper thickness by an operation called "machining."

The sealskin is passed several times through a machine consisting of an ingenious arrangement of air blasts, combs and knives. The pelt is bent sharply over a dull knife edge and the downy fur is blown down or parted by the air blast. The short guard hairs, because of their comparative stiffness, are not blown down by the blast but stick up. While blown down the soft fur is caught and held in place by combs and the short stiff hairs are then clipped off almost at their roots by knives. This operation improves the smooth and soft appearance of the fur to a marked degree.



Courtesy Fouke Fur Company.

FIG. 239.—Fur-seal skins stretched on hoops for drying, St. Louis, Missouri.

The final operation called "finishing" consists of working the pelt into an extremely soft and pliable condition and "setting" the fur so that all the strands lie parallel. The skins are then ready for sale and can be worked directly into garments by the furrier.

It might be mentioned that during the various processes the skins are several times dried and in other ways exposed to increased temperature but in all of these cases very careful control of the operation is necessary as the skins must never be exposed to a temperature above 120° F. as this results in the disintegration of the pelt.

By-Products.

There are a few by-products in the seal industry for which use has been found. As described above, the blubber taken from the seal is rendered and the oil extracted is used to tan the skin itself. The pulp remaining from the rendering of the blubber is found to be suitable for fertilizer. The long guard hair which is removed in the unhairing operation has been found to be very satisfactory as heat insulating material. In the shaving or buffing operation the fluff, which is really the skin removed by the abrasive drum, has been found to be good for fertilizer as it has rather high nitrogen content and also contains some potash.

Hair Seals and Sea Lions.

Species of Economic Importance.

In the North Atlantic and Arctic waters the species hunted are the harp seal, ringed seal, harbor seal and hooded seal. The harp seal is the most numerous and is the chief object of pursuit. The bearded seal and gray seal are rare and taken only incidentally. The Caspian seal formerly produced considerable revenue to the Russian Government. The sea elephants and sea lions have long been practically exterminated by the relentless slaughter for oil. The hooded seal of the seas east of Greenland first began to assume commercial importance in 1761. By 1884 the industry was failing after over 1,000,000 seals had been taken.

List of Hair Seals, Sea Elephants and Sea Lions.

Seals.

1. Harbor or leopard seals, *Phoca vitulina, Linn. and related species.* North Pacific, North Atlantic and Arctic regions.
2. Ringed seal, *Phoca hispida,* Schr. North Atlantic, Bering Sea and Arctic regions.
3. Harp seal, *Phoca groenlandica* Fabr. North Atlantic, Bering Sea and Arctic regions.
4. Ribbon seal, *Phoca fasciata* Zimm. North Pacific and Bering Sea.
5. Bearded seal, *Erignathus barbatus* Fabr. Arctic Coasts south to Norway, Labrador and Plover Bay on the west Siberian Coast.
6. Gray seal, *Halichoerus grypus* Fabr. North Atlantic.

7. Hooded or crested seal, *Cystophora cristata* Erxl. North Atlantic and Arctic Seas.
8. Caspian seal, *Phoca caspica* Gmel. Caspian and Aral Seas.
9. Lake Baikal seal, *Phoca sibirica* Gmel. Lakes Baikal and Oron.
10. Monk seal, *Monachus monachus* Hermann. Mediterranean, Adriatic, and Black Seas; Madeira and Canary Islands.
11. West Indian seal, *Monachus tropicalis* Gray. Gulf of Mexico and Caribbean Seas.
12. Leopard seal, *Ogmorhinus leptonyx* Blainv. Southern Seas, New Zealand and islands to the eastward and southward.
13. Crab-eating seal, *Lobodon carcinophaga* H. and J. Southern and Antarctic Ocean.
14. Weddell's seal, *Leptonychotes weddelli* Gray. Coasts of Patagonia, Tierra del Fuego and islands to the southward.
15. Ross' seal, *Ommatophoca rossi* Gray. Antarctic Seas.

Sea Elephants.

16. California sea elephant, *Mirounga augustirostris* Gill. Coast and islands of California from Cape Lazaro, lower California, to Point Reyes.
17. Southern sea elephant, *Mirounga leonina* Linn. South Pacific, South Atlantic, Indian and Antarctic Oceans.

Sea Lions.

18. Southern sea lion, *Otaria byronia* Blainville. Western coast of South America south to the Falkland Islands.
19. Auckland sea lion, *Phocarctos hookeri* Gray. Auckland Islands.
20. Steller's sea lion, *Eumetopias jubata* Schreber. Bering Strait south to California and Japan.
21. California sea lion, *Zalophus californianus* Lesson. Lower California to San Francisco.
22. Gray sea lion, *Zalophus lobatus* Gray. Coast and islands of New Zealand and Australia.

Habits.

All species of the family *Phocidæ* are similar in their strong social instincts and in their human affection for their young. Most are gregarious, at least during the breeding seasons, patient and submissive, harmless to man, fond of basking in the sunshine out of the water, full of curiosity, voracious, their food consisting of fishes, crustaceans and mollusks. The hooded seal will always resist attack. The harp seal is particularly gregarious, assembling in large numbers on the ice floes to bring forth young. They are able to remain under water for periods of 8 to 30 minutes. But few of the species are migratory. As their flippers or feet can hardly reach the ground, their locomotion on land is clumsy and awkward.

Methods of Seal Hunting.

The methods employed by seal hunters are many and various, depending upon locality, species of animal pursued, and other important factors. The use of nets is confined to the shores and to the periodical visits of the seals to the shore. On the northern shores of Europe, Greenland, Gulf of Bothnia, Caspian Sea and Lake Baikal nets have been used for centuries. The capture of seals by the harpoon is mainly practiced by the Eskimos and other northern tribes. The inhabitants of Norway and Sweden have used several ingenious traps to secure seals such as the *seal box* similar to a rat trap in principle; the *seal hook* which is a hook fastened around the base of a seal rock upon which the animals are impaled when they are frightened to the water; the *"skrackta"* which is a sort of harpoon gun operated by a spring and inset into the seal rock. Rifles and clubs are used on shore and on ice floes.

The capture of seals on ice floes on a large scale for commercial purposes dates back at least to the beginning of the 17th century when vessels were fitted out especially for seal hunting in the Gulf of Bothnia. Clubs and harpoons were used from open vessels and no extended trips were made. Shortly before 1800 larger vessels and later steam vessels began to go to the ice floes of the open seas. Clubs, and at times, firearms were a means of loading the ship to capacity. As many as 25,000 seals have been captured by a single vessel in a season.

TABLE 90

ANNUAL KILLINGS OF HAIR SEALS

Year	Canada	Newfoundland	Total
1911	13,771	304,591	318,362
1912	18,618	175,130	183,748
1913	7,560	272,965	280,525
1914	6,345	233,719	240,064
1915	11,346	47,004	58,350
1916	23,227	241,302	264,529
1917	31,145	196,228	227,373
1918	20,000 [a]	151,431	171,431
1919	6,159	81,293	87,452
1920	4,891	33,985	38,876
1921	2,080	101,452	103,532
1922	5,000 [a]	144,595	149,595

[a] Estimated.

Location and Importance of Industry.

The only important sealing grounds remaining of commercial value lie in the North Atlantic Ocean off the coasts of Newfoundland, Labrador and Greenland. In 1911 Canadian and Newfoundland sealers took 318,362 seals and in 1922 about 150,000 seals. In 1920 only 38,876 seals could be secured and it was estimated that the loss was over $800,000 in that year. In 1922 nine vessels with crews of 1,566 men left Newfoundland ports to hunt seals. Three of these were able to make a second trip, while one vessel with 7,000 pelts was lost. A tenth vessel took 1,564 pelts. There were about 10,000 seals taken from the shore. Airplanes assisted the sealers by locating the herds and notifying the hunters by wireless. The products are both skins and oil.

The methods employed in the preparation and tanning of the hides have been described in Chapter 26 (see page 492).

Preparation of Seal Oil.

The blubber of seals varies in thickness from 1 to 3 inches according to species, age and condition of the animals. It is removed from the pelts usually as soon as they are landed.

Formerly the blubber was simply heaped up in large tanks and allowed to decompose, the oil flowing from the mass as decomposition proceeded. After two or three months the remainder of the oil was obtained by boiling the mass of fat with water.

Small amounts of oil are rendered by heating the finely minced blubber in kettles directly over a fire. As the oil rises to the surface it is skimmed off.

At present practically all of the seal oil is rendered by steam. After mincing, the blubber is placed in large inclosed tanks where it is exposed to the action of steam. The oil obtained is separated from water by passing it through a series of settling tanks, the overflow from the first passing into the second, and the overflow from the second passing into the third, and so on. Seal oil obtained from fresh blubber is termed steam-refined oil. By pressing the steamed blubber, a second quality of dark-brown oil is obtained.

Steam-refined oil is superior to oil obtained either by the decomposition or by direct heating of the blubber, as the color and odor are much less pronounced.

Composition and Properties of Seal Oil.

Crude seal oil deposits "stearine" on standing in the cold which is removed by filtering the oil.

Four commercial grades are obtainable, white, straw, yellow and brown seal oil. As a rule the fresher the blubber the lighter the color of the oil produced, although rendering at high temperature also darkens the oil.

Seal oils resemble cod-liver oils in composition and for this reason are sometimes used as adulterants of medicinal liver oils. The taste is often the most certain means of distinguishing between cod-liver and seal oil. Seal oils contain the fat soluble vitamin A, although the content is not as high as in cod-liver oil.

The characteristics of a sample of seal oil obtained from *Phoca groenlandica* as reported by Chapman and Rolfe are as follows: Specific gravity (at 15° C.) 0.9249-0.9263; saponification value 190.7-196.2 (Mgs. KOH); iodine value 129.5-141 per cent; Reichert value 0.07-0.22 (c.c. N/10 KOH). The insoluble fatty acids melted at 22.33° C., and had a neutralization value of 190.4-196 (Mgs. KOH). These results indicate that while this oil belongs to the drying class it is a relatively poor drying oil and not well suited for use as a paint or varnish vehicle.

Tsujimoto has examined the oil obtained from the blubber of the sea lion *Eumetopias jubata* Schreber with the following results:

Specific gravity	0.9278
Saponification value	189.80
Iodine value	156.37
Acid value	0.58
Refractive index at 20° C.	1.4783
Butyro-refractometer	80.0
Melting point of fatty acids	29.5°C
Ether insoluble bromides (% of total fatty acids)..	36.04%

Evidently this oil was a good drying oil as it contained large amounts of the glycerides of the highly unsaturated fatty acids.

Seal oils are used as burning oils in lighthouses, as substitutes for cod-liver oil, in soap making and in the leather industry, particularly in currying, and in the manufacture of degras and sod oil.

Walrus.

Importance and Location of the Industry.

North Pacific.—The Pacific walrus occurs in Bering Sea and the Arctic Ocean. About June 1 the ice begins to break up and the walrus herd starts northward. During the latter part of June the major part of the walrus herds is found in Bering Strait. In August the movement southward begins and by October they are all back in Bering Sea. One of the important localities in the Arctic is in the vicinity of Cape Serdzekamen, on the Siberian coast. They do not go past Point Barrow on the American side of the straits. Bristol Bay and St. Matthew Island in the Bering Sea were formerly populated with large numbers of walruses.

It was only after the whales began to become scarce in the Arctic region (about 1863) that walruses began to be killed for commercial purposes. Up to 1880 walrus products, oil and ivory, were secured having a value of nearly a million and a half dollars. Since that year the take decreased until in 1902 about 100 animals were being obtained annually. In 1908 the United States Government prohibited the killing of walruses commercially.

North Atlantic.—The Atlantic walrus is now found in Hudson Bay, Davis Strait and the coast of Greenland. In Europe their principal resorts are Spitzbergen, Nova Zembla and the smaller islands of the Arctic Sea. In former days the herds could be found far south of their present limits but the ruthless persecution of these animals speedily exterminated them from the southern part of their range. They have been found as far north as open water occurs.

On the American side of the North Atlantic, during the latter part of the 18th century as many as 1,500 or 1,600 were killed in a single year. In 1909, Dr. Grenfell estimated that not over 50 walruses were killed in a year on the coasts of Labrador. On the European side of the Atlantic the walrus was hunted commercially from the beginning of the 17th century when thousands were killed annually. By 1890 the take had decreased to only several hundred animals annually.

Species of Walrus.

The walruses are confined principally to waters within the Arctic Circle and have no representatives in tropical or Antarctic regions. Probably their most distinguishing feature is the enormous development of the upper canines (tusks) and the great enlargement of the anterior part of the skull for their reception and support. As they exist today the walruses belong to two species.

Odobenus rosmarus, Linn. Atlantic walrus.
Odobenus divergens, Ill. Pacific walrus.

The difference between these species is not great. The tusks of the latter are longer and thinner and generally more convergent with greater inward curvation. The mystacial bristles are shorter and smaller and the muzzle deeper and broader.

Habits of the Walrus.

Although the walruses move about over their extensive feeding grounds they are restricted to the neighborhood of shores and large ice masses and they are not truly migratory. They are huge, clumsy, gregarious animals, huddling together while on the shore or ice. When leaving the water, those arriving first fall asleep near the water. The later arrivals either force them further up the beach or haul out on top of those already there. Unmolested, the walrus is rather inoffensive, but if attacked they become fierce and dangerous antagonists. They rely upon their sense of smell rather than upon sight and sound for protection from their enemies, which are principally the polar bear and man. They cannot endure great fatigue and sleep is very necessary to them. Pursuers have easily taken them by first following them until they fell asleep in the water. The females show strong affection for their young and will rally around a wounded member, becoming very ferocious in its protection. They are monogamous and usually bring forth but one young at a time. Births take place in May or June. Their food consists mainly of mollusca and probably some seaweed. Clams are dug on the bottom of the sea with their tusks which are also used in crawling out on the ice and in fighting.

Methods of Hunting Walrus.

In the early days of walrus hunting the instruments used were the harpoon and lance. From the standpoint of conservation this method was to be preferred to firearms. Practically all the animals wounded and killed were secured and it was not possible to capture many before the herd was driven away. Since 1880, however, rifles have been used and great numbers have been shot at one time. There has been a large loss since a mortally wounded animal will sink to the bottom and cannot be recovered. When a vessel's captain sights a herd of walrus upon the ice, he works the ship to a position to the leeward. A dingey with a crew of a gunner and two seamen is launched. The gunner approaches until he is able to shoot one of the animals. He must be very sure of the first shot because if he only wounds a walrus the whole herd will take fright and disappear. On the other hand if the first shot is immediately fatal he can approach closer and probably land on the ice. There he takes a position behind some lump of ice and proceeds to shoot until ready to quit. The number killed depends upon the capacity of the ship's force. The walruses pay little or no attention to the reports of a gun. Bellowing animals in the water will disturb a whole herd. The scent of man will quickly arouse and scare away the herd. Often a herd will be found on a floe of rotten ice and the warm blood will melt it sufficiently to break when the dead animals generally are lost. There is little danger in walrus hunting with rifles, although there have been cases where tusks have been hooked over the gunwale and the boat capsized.

After a killing has been made, the hide with the blubber is stripped off, the head removed and the tongue pickled for food. On the ship the blubber gives up its oil in the try-pot and the hide is saved by some walrus hunters to be made into leather. The oil and ivory are the products chiefly desired by some hunters.

Products.

The preparation of leather from the hides has been described in Chapter 26.

Ivory.—Walrus ivory is much inferior in value to elephant ivory for the reason that it becomes yellow with age and the tusk contains a large core which is of little value. The outside of the tusk of the male has many cracks. Tusks vary greatly in size and those of the female, while smaller than the male's, are of finer texture and generally free from cracks. The proportion of pith to sound exterior ivory is less in the female tusks. On the whole walrus ivory will allow the manufacture of comparatively few articles and those must be small in size.

The price of walrus ivory varies with the supply. During the 11 years, 1870 to 1880, which was probably the height of the walrus industry the Pacific fleet captured 100,000 walrus, producing 398,868 pounds of ivory and 1,996,000 gallons of oil, having a total value of $1,260,000.

Preparation of Walrus Oil.

The blubber of the walrus averages 2 or 3 inches in thickness. Usually it is not detached from the skin until after the removal of the latter from the carcass when the pelt is placed on a flensing board or platform, skin side down, and the blubber is cut off in irregularly shaped pieces of 10 or 15 pounds each.

When the oil is to be rendered the large pieces are minced, or scored and cut into slices varying from one-fourth to three-fourths inches in thickness. The pieces are then thrown into the try-pot. The pots are usually heated over an open fire. The cooking must be done slowly, the pot being well stirred during the rendering, to prevent the blubber from sticking to the sides and bottom.

The yield of oil averages about 20 gallons per walrus, although the amount varies greatly depending upon the size and the fatness of the animal.

Walrus oil is usually of a light yellow color and has a specific gravity of 0.925 at 59° F. Probably most of the oil produced is mixed with and sold as seal oil.

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Chapter 36.

Commercial Sponges.

By H. F. Moore.*

History of the Industry.

The taking of sponges for commercial purposes was first practiced in the Mediterranean, where knowledge of the occurrence, properties, and uses of these interesting marine animals is of great antiquity as is evidenced by various references to them in the works of Homer and other authors of classic Greece. Apparently, there was an extensive and lucrative sponge trade several centuries before the Christian era, and the sponge fishery was a recognized industry not infrequently mentioned in early Greek literature.

The fishery originated in the eastern part of the sea and was followed particularly by the Greeks of the islands of the Ægean, where there developed a race of daring and hardy divers who during the centuries have known no real rivals in their hereditary calling. They gradually extended their field of operations to the north coast of Africa, and the central Mediterranean, and in more recent times to the coast of Florida and, to a minor extent, other parts of the western Atlantic. The major part of the population of a number of the islands of the Ægean Sea and contiguous waters for centuries has been composed of sponge fishers and their families.

Until 1841, the world's sponge supply was derived solely from the waters of the Mediterranean, but in that year a French sponge merchant who had been wrecked in the Bahama Islands was attracted by the quality of the native sponges, and shipped a sample lot to Paris. Eight years later the exports of sponges from the Bahamas were valued at about $10,000. It was in this year, 1849, that the first Florida sponges were shipped from Key West to New York on a venture that they might find a sale. At this time the American market was supplied solely by the Mediterranean fisheries, and the venturesome cargo from Key West narrowly escaped being thrown away as worthless. Its ultimate sale, however, and a gradual recognition of the merits of these sponges, and their low price, established a small but growing market, and several merchants of Key West began to buy the better grades and take them in trade from the fishermen.

It is said that at first they paid but 10 cents a pound for sheepswool sponges, but, as the product became better known the price improved,

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*** Deputy Commissioner, Bureau of Fisheries.**

capital was invested in the industry, and a class of men developed whose principal business and means of livelihood was gathering sponges.

At first the fishery was confined to the waters adjacent to the Florida Keys, but about 1868-1870 extensive beds of superior sheepswool sponges were found in the Gulf of Mexico, north of Cedar Key, and a little later south of that point, extending as far as Anclote Key. Notwithstanding several attempts to supplant Key West, from which most of the sponges hailed, that city maintained its supremacy as a market until about 1899, when Tarpon Springs, more advantageously located in respect to the valuable Gulf of Mexico grounds, supplanted it. The introduction of diving in 1905, and the establishment of Tarpon Springs as the headquarters for the Greek divers, confirmed the position of that place as the principal market, and at present over 85 per cent of the total product of Florida sponges is marketed through the sponge exchange there.

Although sponges were taken on the north coast of Cuba before that time by Bahama spongers operating under license from the Spanish authorities, it was not until the discovery of the productive beds on the south coast, between the main island and the Isle of Pines, in 1884, that the fishery assumed real importance. An attempt to acquire a monopoly of these beds was frustrated, and they were reserved as a common fishery with the result that within 6 or 7 years they were producing about $110,000 worth of sponges annually, and there were upwards of 180 spongers operating from Batabano alone.

Statistical.

The statistics of the world's sponge production are impossible of statement with accuracy. Those of the United States, the Bahama Islands and Cuba can be stated with considerable exactness, but the fishery of the Mediterranean, the most important of all, is conducted by so many nationalities, overlapping in their fields of activities and in their markets, that it is difficult if not impossible to detect omissions and duplications in the published data. Sometimes it is evident that the same sponges are reported in part both for the country under whose jurisdiction the beds are lodged and by that whose nationals conducted the fishery. For this reason the following table must be accepted with reservations in respect of the Mediterranean production.

	Pounds	Value
Mediterranean (estimated)	....	$2,000,000.00
United States (1922)	667,721	831,457.00
Bahama Islands (Exports, 1920)[a]	1,104,842	556,830.00
Cuba (Exports, 1920)[a]	227,901	324,151.00
Other localities (estimated)	....	10,000.00
		$3,722,438.00

[a] Production not available, but practically all sponges produced are exported.

The production by kinds in the United States in 1922, was as follows:

Kind	Pounds	Value
Sheepswool	398,759	$758,497.00
Yellow	145,477	46,436.00
Grass	113,963	23,690.00
Wire	7,500	2,589.00
Glove	2,022	245.00
	667,721	$831,457.00

The exports, by kinds, from the Bahama Islands in 1919, were as follows:

Velvet	$460,561
Grass	204,205
Sheepswool	159,107
Hardhead	73,839
Reef	70,532
Yellow	28,844
Total	$997,088 [b]

[b] The high valuation was due to high unit prices immediately after the war.

The Living Sponge.

The limits imposed on the length of this article will not permit of more than a cursory account of the structure and life history of these interesting animals.

The living sponge, fresh from the sea, has no resemblance to the sponge of the markets. It is a solid, rather slimy-feeling fleshy body, varying in color from light greyish yellow through a considerable range of browns to black, and in shape it varies with the species, age and habitat. In general appearance and consistency it is not unlike beef liver, and is traversed by numerous chambers and canals.

It is covered by a skin raised at intervals into blunt little cones, and perforated by small pores leading into subsurface cavities. These canals run into the interior, their walls punctured by innumerable minute holes, each of which leads into a microscopic pear-shaped chamber which in turn opens by a larger pore into a canal. These canals, uniting with others, become gradually larger until they again reach the surface in one of the large openings scientifically designated as oscula, but known to the spongers as "eyes," and generally called vents in the descriptions which follow.

The pear-shaped chambers are lined with innumerable microscopic lashes or cilia, which, by their rhythmic beating, set up a current of water entering by the small pores and escaping from the vents, thus carrying food and oxygen to all parts of the sponge.

There are tissues of various, but not markedly differentiated, kinds in the fleshy mass of the sponge, but the important economic feature is the skeleton, which, freed from the fleshy matter, constitutes the sponge of commerce. This is composed of a substance related in general chemical and physical properties to silk, horn, and chitin, the foundation of the shells of insects and crabs. This substance, called spongin, is arranged in a fibrous network differing in structural details in the different sponges, but for each the thickness of the fibers, the sizes of the microscopic meshes, and the relations of the several parts, one to another, lie within definite limits of variation. Embedded in the core of the large main fibers there is always more or less foreign matter, such as sand grains, but an excess of such materials in or on the fibers makes the sponge harsh and otherwise inferior for commercial purposes.

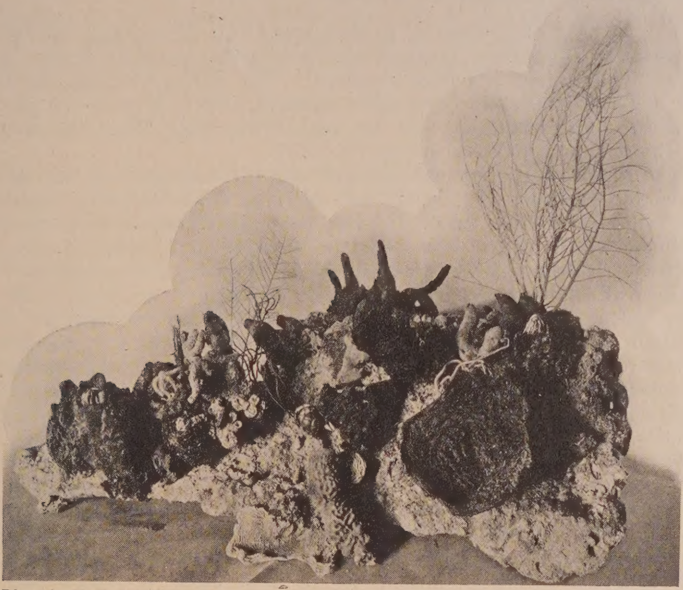

Photo by H. F. Moore.

FIG. 240.—Fragment of "sponge-bottom," west coast of Florida. Shows several species of sponges and other organisms characteristically inhabiting the sponge banks.

Little is known of the life history of the commercial sponges. In some species, if not all, the sexes are distinct, females preponderating. The young produced from the eggs are free-swimming organisms, and are still of very small size when they settle and become permanently attached. This must be a critical stage in their life history, for they are so minute that a very thin stratum of silt would be sufficient to engulf and smother them. As much of the sea bottom is covered with soft or shifting deposits, the mortality at this period must be very high.

Within the limits of variation of the species, sponges, in shape, rate of growth, texture, etc., are creatures of their environment, and when transplanted are often quickly modified in general characters. They require for their existence water of nearly full oceanic salinity. If kept moist, they tolerate exposure to the air for considerable periods during cool weather and in Florida they grow from about low water mark to a known depth of 150 feet, and probably more. In the Mediterranean they occur to depths of 500 to 600 feet. That the food is taken into the sponge wholly or in large part through the canal system is practically certain, but of what it consists and by what tissues it is absorbed, is not known.

Description of Commercial Sponges.

The sponges of commerce, as they appear on the market, are but the skeletons or supporting frame-work from which the soft fleshy matter of the living animal has been removed. This skeleton consists of fibers of a material which has been called spongin, and it is upon the physical properties of this material and the way in which the fibers are disposed that the economic value of sponges depends.

The fibers of commercial sponges vary in diameter, but are always fine and comparatively, but not wholly, free from embedded sand and other siliceous matter which imparts to some closely related species a harshness which makes them unfit for domestic and industrial purposes. The network formed by the fibers is composed of small close meshes. The qualities affecting the commercial value of sponges are color, size and shape, softness, fineness, durability, resiliency and absorptiveness.

Color is the consideration of least intrinsic importance, though for esthetic reasons it exerts considerable influence on the market value. As the color is often incidentally correlated with other qualities, due to local conditions, it is of value in distinguishing the grades and geographical varieties.

Size and Shape.—The most desirable size, and to some extent the shape, depend on the use to which it is to be put. For surgical and some toilet purposes small ones are desired; for the bath a medium size; while for cleaning vehicles a large sponge holding a considerable quantity of water is necessary. Sponges up to 8 inches in diameter are commonly used entire and called "forms," while large ones, or those that are irregular or torn are usually cut into pieces called "cuts."

The valuable commercial sponges are regular, more or less massive, and free from long processes or "fingers." They are spheroidal, cake-shaped, conical, or cupped, or of intermediate shape in great variety. For general purposes the more desirable forms are the spheroidal and cake-shaped, but for such work as applying glaze to pottery, a flat surface is desired and this is generally obtained by cutting up a massive form or by using pieces of a smooth-surfaced lamellar sponge like the Mediterranean elephant's ear.

The more desirable grades of sponges, other things being equal, are those which are softest. Sponges with comparatively slender fibres, with the microscopic meshes rather open, with a small amount of foreign matter embedded in the spongin and with an open canal system, are the softest. Those with the fibres laden with sand are invariably harsh.

Fineness depends upon the macroscopic rather than on the microscopic arrangement of the skeleton, though the slenderness of the fibres is a factor. The Matecumbe sheepswool is one of the softest of sponges, but its open structure makes it appear coarse when compared with Mediterranean kinds. Fineness in the same species, like other qualities, varies more or less with the environment under which the individual is produced.

Toughness and durability vary greatly with the species, and in the same species, with the conditions under which the sponge grows.

Chemistry of Sponges.

Sponges of the markets consist principally of spongin, an albuminoid related to conchiolin found in the shells of mollusks, and fibroin and sericin, the principal constituents of silk. Its composition is reported to be

C 46.50	H 6.30	N 16.20	S 0.50	(Croockewitt)
C 48.75	H 6.35	N 16.40		(Posselt)

Hammarsten[1] gives the following description of spongin: "It gives no gelatin. On boiling with acids, according to the older statements, it yields leucine and glycocoll, but not tyrosine. Zalocostas claims to have found tryosine and also aminoisovalerianic acid and glucalanine ($C_5H_{12}N_2O_4$). After Hundeshagen had shown the occurrence of iodine and bromine in organic combination in different sponges and designated the albumoid containing iodine, *iodospongin,* Harnack[2] later isolated from the ordinary sponge, by cleavage with mineral acids, an iodospongin which contained about 9 per cent iodine and 4.5 per cent sulphur. On the hydrolysis of spongin Abderhalden and Strauss[3] obtained abundance of glutamic acid, 18.1, and glycocoll, 13.9 per cent, also leucine, 7.5, proline, 6.3, and aspartic acid, 4.1 per cent. Very remarkable was the fact that neither tyrosine nor phenylalanine could be detected. Strauss[4] has obtained *sponginoses* of various kinds from spongin by dilute acids. The heterosponginose contained the greater part of the iodine and sulphur, while the deuterosponginose contained the carbohydrate groups. Iodospongin is considered as a derivative of the heterosponginose."

No complete analyses of entire sponges, with the fleshy matter in situ, appear to have been published. The Bureau of Soils, U. S. Department of Agriculture, investigating the organisms as sources of fertilizer, found an air-dry horny sponge to contain moisture 13.90%, silica (SiO_2) 1.41%, nitrogen 7.41%, phosphoric acid (P_2O_5) 1.17% and potash (K_2O) 1.64%.

Sponge Culture.

In 1785 F. Cavolini, an Italian, made the observation that pieces of living sponges would attach to foreign bodies and grow, and in 1862

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[1] Textbook of Physiological Chemistry, Fifth edition. New York (1911).

[2] Zalocostas, *Compt. rend., 107* (1888), 252-4, Hundeshagen, *Maly's Jahresber., 25,* 394, Harnack, *Zeitschr. f. physiol. Chem., 24* (1898), 412-24.

[3] *Zeitschr. f. physiol. Chem., 48* (1906), 535-6.

[4] *Biochem. Centralbl., 3* (1905), 513. See also Strauss, E., Studien über die Albuminoide. Heidelberg. 1904.

Oscar Schmidt repeated the observation and suggested that it offered the basis for developing a method of sponge culture. The suggestion was taken up in 1867 by certain merchants of Trieste who established an experimental station in charge of Gregor Bucich. Since then experiments have been conducted by Munroe, Harris, and the writer in the United States, by Dubois, Allemand-Martin and others in the Mediterranean, and by the government of the Bahama Islands. The essential procedure of all of these experiments has been to cut the living sponge into pieces, which were attached to supports of various kinds in various ways.

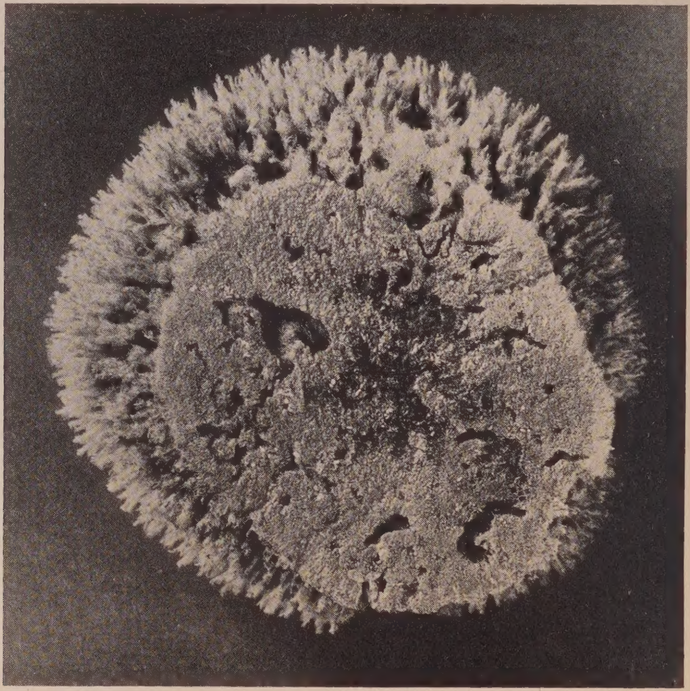

FIG. 241.—Sheepswool sponge. Grown from a cutting attached to a cement disc. Bottom or "root." Note the finely felted surface released from the attachment. This part of a natural or wild sponge is open and torn and comparatively weak.

The method finally adopted by the writer was to fasten pieces of sponge with a volume of about 8 cubic inches to cement discs about an inch thick and ten inches in diameter, attachment being made by means of aluminum wire thrust through the sponge and passing through a hole in the disc. The method, and others, and a more complete history of the subject may be found in papers cited in the bibliography.

The writer's methods were tried on a commercial scale at Anclote Key and Sugar Loaf Key, Florida. At the former location the sponges were killed by an influx of fresh water, and at the latter the project was abandoned for reasons other than technological and biological. It is understood that essentially the same method is being employed with success in the Bahama Islands.

Commercial Varieties of Sponges.

Both the scientific and commercial classifications of economic sponges are confused and unsatisfactory, and the two are often mutually contradictory. These animals are so extremely plastic and susceptible to influences of local environment, changing appearance and details of form and general structure so completely under different physical conditions of the bottom and water, that satisfactory descriptions are almost impossible.

The classification employed in commerce is much more complex than is here indicated, as all of the sponges named are further differentiated according to geographical origin, quality, and even the methods by which they are taken. Among American sponges, in addition to the various geographical and local designations, we have "forms," "cuts," and "seconds," while in the Mediterranean certain of the commercial species are subdivided into "fines," "commons," "seconds" or "rejects" (écarts), "plongées," "harponées," etc. The significance of the discrimination between the same kind of sponges taken by different means is that they may come from different depths of water, may receive different care in curing, or are less mutilated by one type of apparatus than by another.

Sheepswool or Wool Sponges.

These are the best of the sponges of the western Atlantic, and in some of their qualities and for some purposes are not equaled by any other kind. They are massive in form, usually cake-shaped or like inverted pineapples, and regular in contour, with the exception of certain specimens from Cuba which have a flat incrusting base from which rise long teat-like tubes often reaching a length of 6 to 8 inches.

Sheepswool sponges are particularly responsive to environment, exhibiting wide local variation both in appearance and quality, and when transplanted from one locality to another undergoing marked change in character. The oscula ("eyes") are large, few in number, confined to the upper surface, and surrounded by a rampart of flat tufts usually slightly elevated above the surrounding tissue. The whole surface of the skeleton is tufted with fascicles of fibers, which are usually more slender and pointed in sponges from shallow water. Sheepswool sponges grow to a large size, 18 inches or more in diameter, and are soft, absorbent, and the better grades unequaled in wearing qualities.

The smaller and medium sizes are marketed as "forms," while many of the larger ones and the irregular or torn ones are divided and sold as "cuts."

Unbleached sheepswool sponges are used for washing railroad cars, automobiles, and other vehicles; by tile and bricklayers, painters, decorators, potters, tanners, etc. Key wool, on account of its softness, is said to be particularly desirable for lithographers. When bleached, they are used principally for bath and household purposes. The best sheepswool sponges are the "Rock Island" sponges from the west coast of Florida, the successively less valuable grades being those from the Florida Keys, Bahama Islands, and Cuba. Those from Mexico, Honduras, and other localities in the Caribbean are inferior.

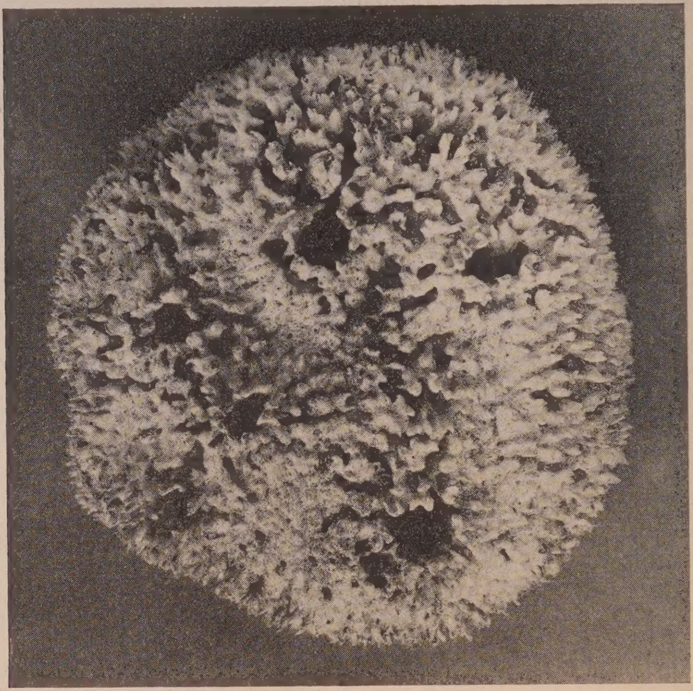

FIG. 242.—Rock Island (Florida) sheepswool sponge. Upper surface.

Yellow Sponges.

Next to the sheepswool, these are the most valuable of the sponges of the western Atlantic, owing to their abundance and wide distribution, although their unit price is a little lower than that of the velvet sponge, next described. Yellow sponges are the most elastic and resilient of American sponges, with the exception of Anclote grass, but are harder than sheepswool, harsher to the touch, less absorbent, less retentive of water, and less durable. They are regular in shape, attractive in appearance, and reach a maximum diameter of about 18 inches. The color is yellow or yellowish brown, those from some localities being tinged with rusty red. The surface is devoid of the long fibrous filaments characteristic of the sheepswool, being covered with a nap of short bristles of uniform length.

In their natural state yellow sponges are used for many of the same purposes as the sheepswool, but are distinctly inferior where softness and a copious water content are required, as in washing vehicles, and they wear out much more quickly. Owing to their hardness and comparatively harsh surface they are said to be particularly useful for scouring and sponging cloth. The best of the yellow sponges, the softest and most durable, come from the Florida Keys, particularly the vicinity of Matecumbe Key. Other yellow sponges on the market come from the west coast of Florida ("Anclote yellow"), the Bahamas, and Cuba. They are also found in the Honduras, Haiti, and other places in the Caribbean. Similar sponges have been reported from Australia, New Zealand, and some of the Pacific Islands.

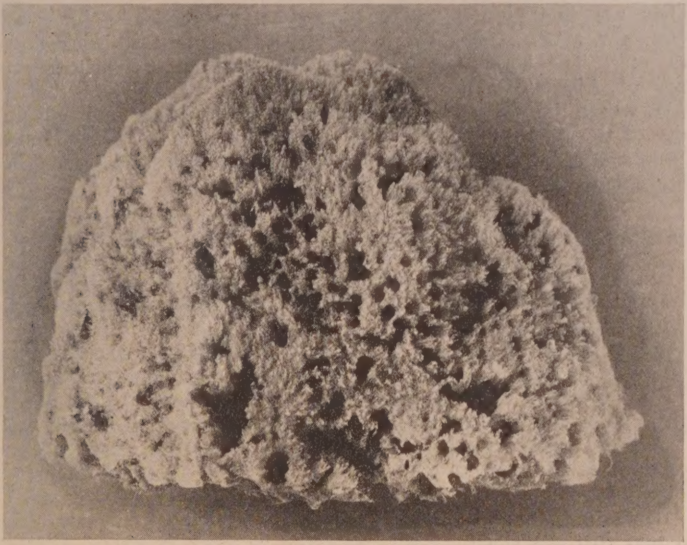

Fig. 243.—Anclote yellow sponge. West coast of Florida.

Velvet Sponges.

Velvet sponges are generally cake-shaped or spheroidal. The surface is devoid of the pointed or sharp-edged tufts characteristic of the wool sponges or the harsh bristles of the yellow, being formed of rounded or flattened soft cushions, the outer faces of which lie in the same plane, imparting a smooth appearance. These cushions may form meandering ridges or flat brush-shaped tufts. The vents or "eyes" are characteristic, one to three large ragged holes in the upper surface, dividing internally by irregular torn-looking septa into numerous circular openings. Jamaica specimens differ in being higher than broad, often sub-columnar, and the vents are single or double rows of openings on the summits of branching crests running across the top of the sponge, an arrangement which makes, in effect, a gash more or less completely across the upper surface.

Good velvet sponges are very soft to the touch, but, in wearing qualities, compressibility, and absorptiveness, are inferior to sheepswool, to which they are next in value, though not differing much from the yellow in that respect.

They are used for household purposes, about boats, for washing vehicles, for general purposes in factories, by painters, brick and tile layers, etc. The best come from the Bahamas, particularly from the vicinity of Abaco Island. The Cuba velvet is better than that from Florida, where the species is found in but small numbers and only in the vicinity of the reefs at the southern end of the state. British Honduras has produced a few velvet sponges about equal to those of Cuba. Those from Mexico and Haiti are inferior.

Grass Sponges.

The grass sponges of commerce comprise a group of several zoölogical species and each varies to such an extent with locality that space will not permit an attempt at description.

The best are the Anclote grass sponges from the west coast of Florida, which grow to large size and for that reason and on account of their hollow waste-basket shape are generally sold as "cuts." They are dirty brown in color, harsh to the touch, highly elastic and resilient, but will not hold as much water as other grass sponges. They are especially useful where there is much oil, as greasy matter is readily washed out of them.

The grass sponges from the Florida Keys, Bahama Islands, and Cuba are various in form and general appearance, but all are entirely different from that just described. They are more compact in shape, softer and much weaker in texture. Especially when bleached, some of them make soft, attractive bath sponges, but they have little durability. They are used as unsatisfactory substitutes for the better grades of sponges, but where softness and absorptiveness rather than wearing qualities are desired, they are useful. There are some good sponges of this type in the Philippine Islands.

Glove Sponges.

The shape of the glove sponge is almost invariably that of a short, stout column, with the sides fluted with irregular vertical ridges between which are one or two rows of round holes about ⅛ inch, more or less, in diameter. These ridges are frequently swollen at their free margins, and they always bear long ragged pencils of fibers. They begin just above the base of the sponge, and extend over the top, near the center of which is a large ragged edged compound vent.

Glove sponges are found on the south and west coasts of Florida, and in the Bahamas. They are soft and elastic, but on account of their open texture and weakness have little value. Those from the west coast of Florida are worthless.

Wire Sponges.

These sponges have a fine massive regular shape, and an attractive color and texture, but owing to their harshness, lack of strength, and inability to hold water they are of little usefulness. Formerly they were rarely brought in by the spongers, but the Greek divers now market a limited quantity. They are bleached and sold, often fraudulently, as substitutes for the Mediterranean bath or honeycomb sponge. They are taken on the west coast of Florida.

Reef Sponges.

Reef sponges are a miscellaneous lot belonging to several zoölogical species and vary in shape, although comparatively uniform in qualities and surface appearance. The surface mesh is regular, covered with short bristle-like bundles of fibers, and bears innumerable round orifices about $\frac{1}{16}$ inch in diameter. Superficially they resemble some of the finer grades of Mediterranean sponges, but the pores are larger, the projecting bundles of fibers stouter and stiffer, and they are far inferior in strength and durability. A few of these sponges are taken among the Florida Keys, but those found in the markets come from the Bahamas and the north coast of Cuba, and, of inferior grade, occasionally from Honduras.

They are used by jewelers, silversmiths, and other manufacturers requiring a small, soft sponge, and as desk sponges. When bleached, they are used for toilet purposes.

Hardhead Sponges.

These constitute another miscellaneous group, some of which are indifferently assigned to this or the preceding, as they may be softer or harder. They are less compressible than reef sponges, and more harsh, elastic and resilient. They are, in general, regular in form and, like the reef sponges, usually small. The softer ones are used for the same purpose as reef sponges, the harder ones for scouring and similar operations where a certain degree of attrition is desirable. They come principally from the Bahamas, the north coast of Cuba, and Honduras, and occasionally from Haiti.

Turkey Cup and Turkey Solid Sponges.

These and the kind next described are also known as "silk" sponges. They are the finest and softest, one of the most elastic sponges known to the markets, and notwithstanding their delicate texture are very durable. Some of them are massive, when they are known as solids, but many are more or less cup-shaped, though perfect cups are rare and, being highly prized, bring high prices. It is said that large, unusually choice, specimens have sold for $50.00 each.

The oscula or vents are comparatively large and numerous, and are grouped on the upper surface of the solids or in the cavity of the cups. There are numerous small round or polygonal pores on the general surface, the partitions between them being very thin and beset with long slender and very soft fibrous pencils. Foreign bodies in the fibers are sparse and this, with the rather open elongate meshes of the microscopic structure, give the sponge its exquisite softness and firmness.

These sponges come from the eastern Mediterranean, the very finest from the Syrian coast. It is stated that the best of them grow in the semi-darkness of caves, crevices, and under over-hanging ledges. They attain a diameter of 8 inches, but rarely, and most of those reaching the market measure but a few inches across. They are used for the more exquisite purposes of the toilet.

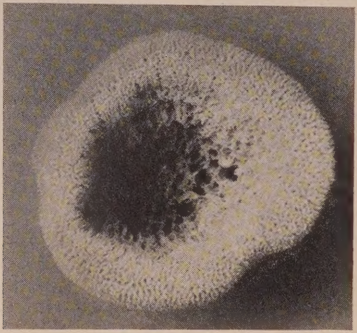

Fig. 244.—Turkey cup sponge. Eastern Mediterranean.

Turkey Toilet Sponges.

Most of these sponges belong to a zoölogical sub-species differing from the preceding, but some inferior Turkey solids are often included in this commercial class. They are flatter than the cup sponges, and have a broader basal attachment to the rocks. The vents are usually distributed over the upper surface, excepting toward the edge, but are sometimes in groups. Generally each is surrounded by a rampart of bristles. The surfaces other than those bearing these openings are perforated by numerous fine pores, and the intervening ridges have sharper edges than in the cup sponges, and the pencils of fibers which they bear are shorter, stouter, and stiffer. The sponge is less compressible and not so soft to the touch. Toilet sponges are found generally on all of the sponge grounds of the Mediterranean eastward from the Adriatic and the Tunisian littoral. They are used for toilet purposes, in leather dressing,

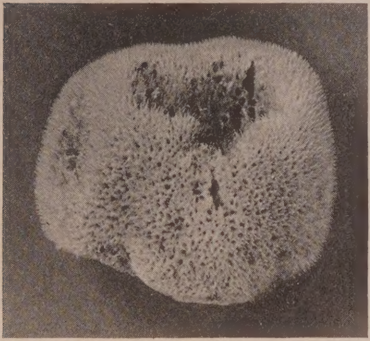

FIG. 245.—Toilet sponge. Mediterranean.

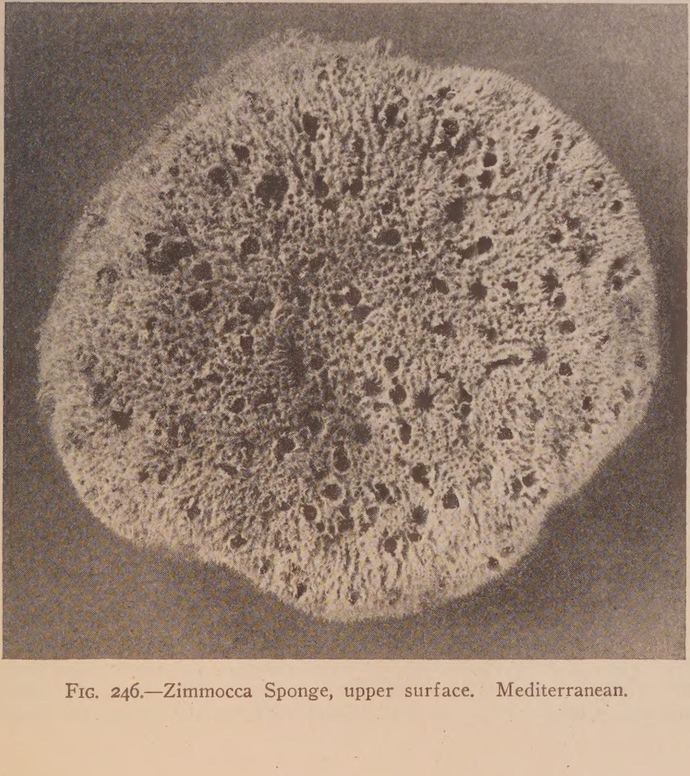

FIG. 246.—Zimmocca Sponge, upper surface. Mediterranean.

applying glaze to fine pottery, and other operations in the arts which require a fine soft sponge.

Zimocca Sponge.

These are massive sponges, usually flatly conical, attached by a relatively small base, sometimes flat on top, sometimes concave, occasionally cup-shaped. The vents lie on the upper surface, usually generally distributed, but occasionally in irregular, radial rows, and in many cases surrounded by a hedge of bristly fibers. The outer surface is formed by a network of narrow ridges, inclosing numerous small pores and bearing short bundles of fibers which become longer and softer upward.

These sponges are taken commercially along the coasts, and about the islands of the Mediterranean, from the Adriatic eastward, southward, and westward to Tunisia and the banks of Lampedusa. They have been taken in small quantities west of this region to the coast of Catalonia.

They are used by potters, leather workers, and, when bleached, for toilet purposes.

Honeycomb or Bath Sponges.

These are massive cake-shaped sponges attached by a broad base. The vents are scattered over the upper part of the sponge and only occasionally are surrounded by a hedge of fibers, usually opening on the general surface, which is composed of superficially expanded plates of fibrous tissue, often extending as a network over sub-surface chambers, clothed with small blunt tufts, particularly around the edges of the numerous circular, polygonal or meandering openings. The general superficial aspect of the sponge is less shaggy than the sheepswool, and not so smooth as the velvet sponge.

Honeycomb sponges are generally distributed throughout the Mediterranean, along the north, east, and south shores from the Gulf of Lyons to Algeria, including many of the islands and the banks of Lampedusa. The Mandrukas are the best, compact, soft, and fine, but those from Tunis, Crete, and Asia Minor are little inferior and often sold as Mandrukas. Those from Tripoli are rough and coarse, and most of those from the Archipelago but little better.

The best of these sponges are softer than any American sponge excepting the Matecumbe sheepswool, but they are less durable and resilient than the Rock Island wool, and more quickly lose their elasticity in use.

Honeycomb sponges are very popular for bath purposes, and they are also used by jewelers, silversmiths, leather workers, and as desk sponges by bank tellers, etc.

Elephant-ear Sponges.

These are cup-shaped or cap-shaped, with thin walls of uniform thickness or more or less rolled ear-shaped or fan-shaped plates about one inch thick. They usually reach the consumer cut into flat pieces, the shape of which gives the name of "wash-rag sponge." The vents are confined to the inside of the cups, or the concave faces of the plates, in groups of

4 to 6 surrounded by tufts of fibers longer than those on the rest of the sponge.

These groups are generally in radial rows, and the face of the sponge, on which they open, often has the appearance of being radially grooved. The opposite surface is covered with soft fibrous tufts, which tend toward a radial arrangement near the rim. Elephant-ears are taken commercially in the Adriatic, the Ægean, on the coasts of Egypt, Tunis, and Algeria, and about the Balearic and Lampedusa Islands. They are fine, soft and durable, and are used for toilet purposes, and by potters, fine leather workers, cane makers, hatters, and others requiring a sponge with those qualities and flat shape.

A sponge of very similar appearance, but much denser and harsher, is found in the Philippines.

Methods of the Fishery.

Sponges grow attached to the bottom, or, less frequently, to other objects under water, the few unattached individuals, usually of spheroidal shape and known to the spongers as "rollers," being those which have been violently torn from their attachments.

The first sponges gathered in Florida, and probably in other regions, were plucked by men wading in the shallows, and to this day the natives of the southern part of Tunisia follow a similar method, wading in the water to their necks, detaching the sponges with their toes, and kicking them within reach of their hands and occasionally diving into the deeper holes.

Nude Diving.

This is another ancient method which followed logically the primitive method first described. It is practiced principally in the Mediterranean, and but little or not at all in the sponge regions of the western Atlantic. The islands of Calymnos and Syme have been noted from ancient times for the skill of their divers, some of whom are said to be capable of descending to a depth of 240 to 250 feet. Ordinarily about 2 minutes is spent under water, and about 30 minutes between plunges, but unusually expert divers can remain under water for 4 minutes, and in one or two cases 5 minutes' immersion has been recorded, but probably in but moderate depths. The Syrians, Tripolitans, and Tunisians also practice nude diving.

To carry them quickly to the bottom the divers carry flat stones attached to a line, the other end of which is held in the boat. When the diver reaches the bottom he drops the stone, but retains hold of the line, or has it attached to his arm by a short lanyard or becket, so that he is free to walk about without losing touch with it. The sponges are deposited in a net bag attached to the diver's waist, and when he is ready to ascend he jerks on the life-line and is rapidly hauled to the surface.

Nude diving requires more skill and training than "machine" diving, is not attended with the serious physical effects which attend that practice, but it is not so productive. This method is most useful on bottom too rough for dredging, where the sponges are hidden in crevices or under ledges which hide them from harpooners or where sharp rocks are liable to injure the diving suit or hose.

Hooking and Harpooning.

These methods are essentially the same, although their instruments differ. Neither can be used when the sea is rough or the water turbid, and those employing them often lose much time by enforced idleness.

The harpoon is used in the Mediterranean sponge fisheries only. It resembles the ancient trident, but may have from two to five barbed points or prongs, the type varying locally and with the nationality of the user. The steel heads are attached to poles about 20 feet long and 1½ inch in diameter. At the free end of the pole a short piece of wood is lashed, so notched as to leave a space between itself and the pole, into which the head of a second harpoon may be thrust and held in place by slipping over it a rope ring or becket. In this manner three or four harpoons are sometimes lashed together in order to reach sponges in deep water. The sponges are sighted by means of a "water-telescope," a cylinder of sheet iron about 8 to 10 inches in diameter, and 15 inches long, with a sheet of glass closing one end. When the closed end is thrust a few inches beneath the surface of the water the bottom and what lies on it becomes clearly visible in moderate depths.

The apparatus is used from small boats about 20 feet long, usually provided each with a lateen sail and two pairs of oars, the latter being the means of propulsion when sponging. A man crouches in the bow watching the bottom, and when a sponge is sighted signals to the oarsman to maneuver the boat into a proper position. He then inserts the harpoon into the sponge, which is detached by a series of gentle jerks accompanied, if necessary, by a rotation of the pole.

Hooking is the American variant of this method, the differences in practice being that instead of the harpoon the instrument of capture is a hook, with three recurved un-barbed points, the water telescope is an ordinary wooden bucket with a circle of glass replacing the wooden bottom, and that the boat or dinghy carries but two men instead of four and is propelled by a single oar skulled over the stern. The length of the poles varies with the depth of water, the longest being 50 feet, used in depths of 40 to 45 feet. Very few men have the strength, eyesight and skill to work in such deep water, and even the best may suffer hernia and other injuries from the strain imposed.

Hooking was the only method of sponging practiced in Florida until the introduction of the diving dress on the west coast, and it is, or was until recently, the exclusive practice in Cuba and the Bahamas.

Machine Diving.

The diving suit or scaphander has been employed in the fisheries of the Mediterranean since about 1866, but it was not until 1905 that it was successfully introduced in Florida. Its advantages are that it permits the exploitation of deeper waters than is possible by the use of the methods already described, and therefore vastly extends the available sponging grounds; that the sponges on those grounds are better and more abundant, and that operations may be conducted under weather and water conditions which would be prohibitive to those methods. The disadvantages are that more capital and equipment are required, and that there is greater peril to the life and health of the divers.

The diving suit is of the usual type, completely covering the body with the exception of the hands, made of two layers of waterproof cotton cloth with rubber between, a tinned copper helmet, breastplate and weighted shoes. The helmet has four heavy glass windows, and a hose connection and a relief valve at the back. The automatic relief valve for the discharge of vitiated air does not appear to be in favor with the sponge divers who prefer the spring valve opened as necessary by pressing against it with the back of the head. The pump is of the usual type used by divers, and the hose which conveys air under pressure to the helmet is of the highest quality, protected by a canvas jacket and the weight of the screw couplings between its sections is compensated in the water by the buoyancy of cork floats.

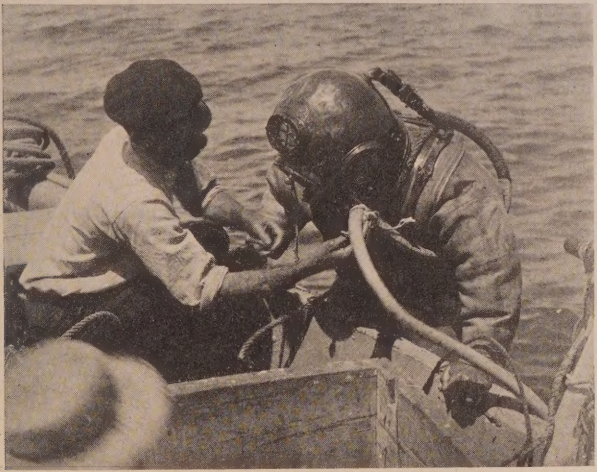

Photo by H. F. Moore.

247.—Sponge diver coming over the side of diving boat. Tarpon Springs, Florida.

Sponge divers, both in the Mediterranean and in Florida, are almost exclusively Greeks, and the Greek type of diving boat is used in both places. They are "double-ended," high bow and stern, and with considerable shear, features which make them seaworthy and dry in any weather. They are usually rigged with a spritsail, but all of those in American waters now use gasoline engines, a cage of metal bars around the propeller preventing the fouling and cutting of the hose and life line. Formerly, even in the engined boats, oars were used in keeping the boat up to the diver as he moved over the bottom, but experience has taught the possibility of using the engine for this purpose. Space will not permit a detailed description of this method of sponging. Let it suffice to say that when the diver is fully dressed and hose and life-line attached, the pump is started and he lets himself over the side of the boat and sinks to the bottom. When he lands he gets to his feet and moves about in search of sponges. Owing to the resistance of the water and buoyancy of his air-filled dress he is unable to walk in the ordinary way but progresses in a series of leaps upward and forward. As sponges are found, they are placed in a bag, which, when full, is hauled to the surface on the life-line and an empty one sent down. Communication between the diver and the boat is maintained by a code of tugs on the life-line.

The length of time that a diver can remain under water depends on the depth and the physical powers of the man. On the Florida coast, in depths of 60 feet or less, the shift is usually two hours down and two hours rest. In deeper water, the period of submergence is shorter and the rest longer.

The divers in deep water are subject to the "bends," or caisson disease, due to the release of air in bubbles in the blood vessels as a result of the rapid change from the pressure in the helmet to that of the atmosphere when they are brought to the surface. Owing to the comparatively shallow water in which diving is conducted in Florida, fatal or serious cases are few there, but the proportion of deaths and disablement among the Mediterranean divers is high, and for their protection the Greek laws prohibit marine diving in a greater depth than 38 meters. This law appears to be generally ignored.

Both the naked and machine divers abstain from eating until the day's work is completed.

A new type of mechanical diving aid known as the Fernez apparatus, has come into use in the Mediterranean since about 1912. The diver is naked, excepting for a rubber mask fitted with goggles, air valves, tubes, etc., and the air is carried from a small pump on the boat, through a hose, to a small reservoir attached to the back by a belt, and thence to the mask and its respiratory appliances. It is reported to compare favorably with the scaphander in the same depths, usually from 20 to 40 meters.

Dredging or Trawling.

This method of sponging is confined to the Mediterranean, where it is practiced principally by Greeks and Sicilians. The dredge, gangava of the Greeks, or gagova or cava of the Italians, is a special type which has been developed for this fishery. The frame consists of a heavy round steel bar about 35 feet long and 2½ inches in diameter, bent at right angles about 12 or 15 inches from each end. These turned-up ends are formed into sockets, into each of which a stout wooden stake is driven and secured by metal pins or bolts. The bar and stakes form the lower side and ends of the frame, the upper part of which is a wooden beam about 6 inches in diameter, with rabbets near the ends to receive the tongues or flattened ends of the lateral stakes. There are several transverse steel struts connecting the steel and wooden bars, the whole forming an open rectangle about 32 feet long and 20 inches wide. To this frame is attached

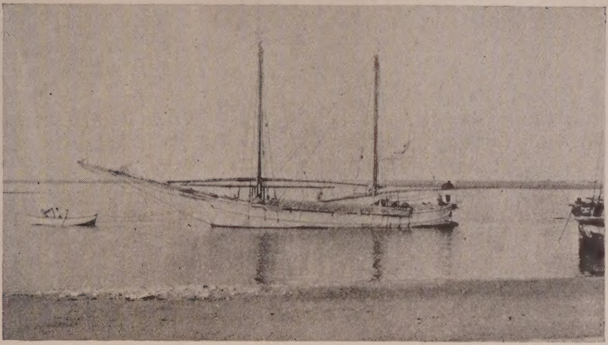

Photo by H. F. Moore.

FIG. 248.—Italian Gangava, or sponge trawling vessel, being towed out of the Harbor of Sfax, Tunisia.

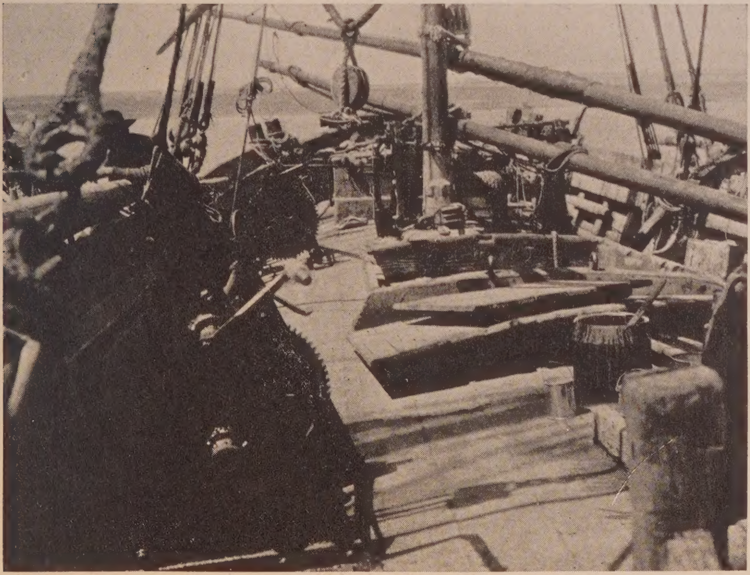

Photo by H. F. Moore.

FIG. 249.—Italian Gangava boat, Sfax, Tunisia. Showing the deck arrangement of boat used in trawling for sponges.

a quadrangular net of about ¼ rope, with a mesh of from 2½ to 3½ inches bar. A bridle is formed by a rope running from the middle of the wooden beam, and three or four chains attached to the steel bar near the ends and at one or two intermediate points, all united in an eye or ring to which the towing warp is attached.

This apparatus is towed at a speed of about 1 to 1½ knots per hour by sailing vessels of about 20 to 40 tons burden, fitted with three winches and the necessary davits and towing bitts, which cannot be described in detail within the limits of this chapter. When in use, the relative lengths of the several members of the bridle, the buoyancy of the wooden beam, and the weight of the steel bar, keep the frame erect with the bar scraping the bottom and tearing loose the sponges and other organisms on the bottom, which are retained in the bag. From time to time the gangava is hauled aboard and the contents of the bag discharged on deck and sorted, the sponges being retained and the considerable quantity of debris dumped overboard. The crews consist of about six men each.

Preparation of Sponges for Market.

The preparation of sponges for market is a comparatively simple process. When taken, the living sponge is covered with a "skin" or membrane, and a large part of the interior is filled with a soft, pulpy, fleshy substance. Both of these must be removed, leaving the skeleton clean. The sponge is first killed and then macerated to liquefy the putrescible matter which is then washed and squeezed out.

The hookers in Florida formerly killed their sponges by prolonged exposure to the air, "roots" down, on the decks of their boats, after which they placed them in "crawls" about 10 feet square, made by driving mangrove stakes close together in shoal water. After an interval of about a week they were removed, beaten with a short heavy stick and squeezed repeatedly under water. When properly done this removed the fleshy matter thoroughly, but the rolling of the sponges on the sandy bottom of the crawls loaded them more or less with sand.

When diving became common on the Florida coast, the Greeks introduced the methods used in the Mediterranean. The sponges are placed on deck and killed by thorough treading under the bare feet of the crew, after which they are strung and hung over the side of the boat to macerate and then thoroughly washed on deck in tubs of sea water.

Unless these processes are thoroughly performed, some fleshy matter or skin is left adhering to the fibrous skeleton, and after drying is very difficult to remove. Such improperly cleaned sponges are said to be "gurried."

After being cleaned the sponges are strung on rope yarns six feet long, the ends of which are tied together to form wreaths, called "bunches." The sponges are partially dried and carried to the primary markets, where they are sold to the dealers at auction in lots.

In the hands of dealers the sponges are trimmed with sheep shears to remove the irregularities and torn parts, gross foreign bodies such as shells, pieces of coral, etc., are removed and are sorted into sizes. The sizes are designated by the number of pieces required to make a pound,

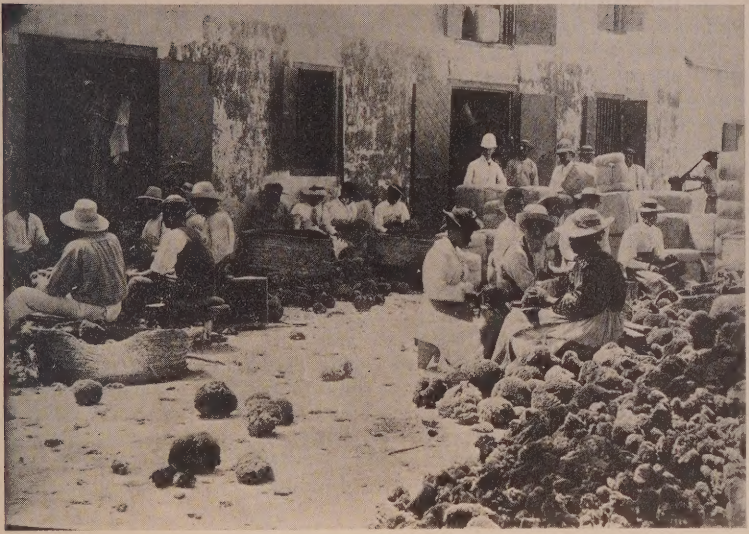

FIG. 250.—Trimming sponges, Nassau, Bahama Islands. Square type of bales used in the sponge trade of the western Atlantic shown in background.

and are usually "ones," "twos," "twos to threes," "threes to fours," "fours to sixes," "sixes to eights," "eights to tens," "tens to twelves," "twelves to sixteens," "sixteens to twenties."

In Florida, Cuba, and the Bahama Islands, the different kinds and sizes of sponges are packed separately in quadrangular sided bales covered with burlap and strongly roped, while under compression in a screw press. The bales vary in size according to the immediate demands of the trade.

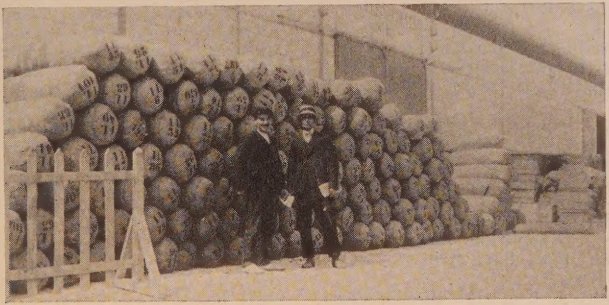

Photo by H. F. Moore.

FIG. 251.—Sponges ready for shipment by steamer. Sfax, Tunisia. Shows cylindrical type of bale used in the Mediterranean sponge trade.

In the Mediterranean, sponges are packed under foot pressure in cylindrical bales weighing about 40 to 75 pounds, or in boxes.

Sponges sold by weight are frequently artificially "loaded" by the wilful introduction of foreign matter, sand or marble dust being usually employed for the purpose in the Mediterranean, while the Americans use more elaborate methods, the "dope" introduced usually consisting of some combination of such materials as sand, salt, epsom salts, barytes, glycerin, dextrin, etc.

Most of the sponges from the western Atlantic are sold in their natural color, but some are bleached, as is a large part of the Mediterranean product. The method usually employed is as follows: Soak the sponges for about ten minutes in 5 per cent hydrochloric or sulphuric acid; then thoroughly wash in water and place in 5 per cent potassium permanganate solution until they have assumed a very dark brown, almost black, color; thoroughly wash again in fresh water and place, until almost decolorized, in a 10 per cent solution of oxalic acid. After another very thorough washing, place them in a 10 per cent solution of sodium carbonate (washing soda) until they assume a bright yellow color. A very thorough washing completes the process. The fiber of all chemically bleached sponges is more or less injured by the treatment, and though softer they are inferior to the natural sponges in durability and resiliency and soon become soggy in use.

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Chapter 37.

Some Problems of the Fishery Industries.

Until recently, but few researches looking towards the improvement of fishery products and the utilization of by-products had been conducted. During the past ten years, however, many of the processes of preservation of fish and fishery products have been improved, and while there is much room for improvement in practically all the methods of the fisheries, a beginning has been made in the application of science. Many millions of pounds of valuable food, and many thousands of tons of non-edible fish which might be converted into excellent animal feed and fertilizer are wasted annually. For the most part the commercial methods have developed empirically without definite knowledge of the underlying scientific principles. For this reason, the field offers tremendous opportunities to the well trained scientist willing to give a few years to the study of these problems.

The problems are legion and are widely varied in nature. It is impossible to say which is the most important problem for no one knows where any investigation will lead. For instance, when the study of methods of salting fish in warm climates was made, it was found that the physical properties of the salted fish could be controlled largely by varying the amount of calcium and magnesium compounds present in common salt. Further, it was learned that pure salt produced soft flexible fish with an appearance and taste resembling that of fresh fish.

A number of fishes are little utilized today, either because of unfounded prejudice against them or the ignorance of the general public regarding their qualities. Investigations have proved that many of these fishes are excellent food, e.g., shark, dogfish, or grayfish, squid, many skates and sablefish. Hundreds of other fishes entirely unknown to the general public, doubtless are of equal or greater value for food. Widespread advertising campaigns to familiarize the public with the qualities of these fish should be conducted. This is especially important in the case of the dogfish and shark, as these fish have been permitted to live almost unmolested for centuries. They are ravenous eaters and many of the larger sharks are exceedingly destructive to fishermen's nets. The grayfish have the habit of following the cod and haddock; at times more of these are caught than ground fish, and are usually thrown back into the sea.

The edible qualities of all fish and other marine animals existing in sufficient quantities to be of economic importance should be investigated. Comparatively little is known concerning the vitamin content of fish and fishery products. The discovery of the presence of large quantities of fat-soluble vitamin A in fishery products other than the liver oils would immediately increase the consumption of these products. Drummond has found this vitamin in whole herring but he has not indicated in which part of the fish the vitamin is concentrated (see page 277).

The modern science of nutrition has shown that all proteins are not of equal value because of deficiencies in certain amino acids. Osborne, Okuda, and others have determined the hydrolytic cleavage products of the proteins of cod, halibut, porgy, and bonito muscle (see page 273), and have indicated the nutritive value of these proteins, but a great deal remains to be done as the proteins of many fish have not been studied.

Fig. 252.—Fishery Products Laboratory of the U. S. Bureau of Fisheries, Washington, D. C. This laboratory is used solely for researches on problems of the commercial fisheries.

When the vitamin content and the nature of the proteins of fish have been ascertained, fishery products may be given their proper place in the diet. Doubtless such investigations will indicate food values hitherto unsuspected.

A problem of great importance, the solution of which was only recently undertaken, is the examination of fish as a source of insulin, the substance recently discovered to possess valuable therapeutic properties for the cure of diabetes. Many fish possess pancreatic glands containing large quantities of this invaluable remedy. Various species of sharks have recently been examined to determine their relative value as potential sources of insulin. The shark has been found to contain this therapeutic substance in a form which can be easily extracted. If this investigation proves the shark to be a valuable source of insulin the fishermen will possess a new source of revenue.

Another problem of great industrial importance which is being solved is the freezing of fish in brine by a small, low priced equipment. Its successful solution will enable the fishermen to quickly freeze small quantities of fish economically. Much important research work along this line has been carried out in the Fishery Products Laboratory of the Bureau of Fisheries. A moderately priced continuous brine freezing apparatus (see page 301) is being perfected which constitutes an important advance in brine freezing methods.

When mackerel, alewives, and herring are repacked the original pickle or brine is usually discarded. When salt was cheap, it hardly seemed worth while to attempt to purify this brine or recover the salt, but during the World War, when salt was very scarce, several investigations were undertaken. The most successful of these processes utilized the absorptive properties of silica precipitated in the brine. After filtration, the purified brine was saturated with salt and again used on the repacked fish. This process has several advantages, viz., low cost, simplicity, and much protein is recovered which may be converted either into animal feed or fertilizer, etc. Unfortunately few packers of salt fish care to try anything new or will devise suitable mechanical equipment for the necessary operations. Any firm willing to employ an expert chemical engineer for a few months ought to be able to perfect the mechanical and chemical details of the process and thus reduce its salt requirements for repacking fish to practically nothing.

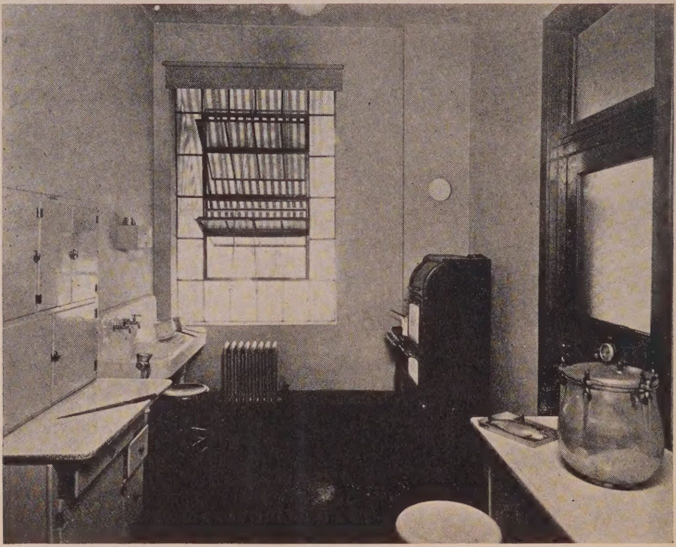

FIG. 253.—The experimental kitchen of the laboratory shown on page 693.

Perhaps no single problem of the fish salting industry has received so much attention as the reddening of salted, dried fish. Hard dried fish are not affected by this pest to any considerable extent, but in recent years the American consumer has been demanding better and better cod. The slightly dried, boneless "steaks" which are particularly susceptible to this bacterial growth have become very popular. Mixtures of boric acid and salt, and sodium benzoate and salt have been almost universally used to check this pest. These antiseptics are of much value in retarding the growth of the reddening organisms, but, in spite of their general use, many thousands of dollars' worth of salted ground fish are lost each year. Bechwith, Bitting, Browne, Edington, Farlow, and others have isolated the organisms which cause the trouble, and have shown that they are present in practically all sea salt and salt marshes, and that they grow on the walls and floors of most fish-salting factories. Many remedies have been suggested that would doubtless help the situation. Mined and refined salts are free from the infection and therefore their substitution for solar sea salts should lessen the loss. The sea salts, which are now so much in favor among fish salters, could be sterilized by heating. But all are agreed that such measures will not be of value unless certain sanitary measures are simultaneously adopted. The fish salting plants must be thoroughly disinfected, and kept free from the infection at all times. The use of concrete floors and walls in the fish salting establishments will facilitate these sanitary measures.

A problem of an entirely different nature but of equal or greater importance is the prevention of the rusting of salted, smoked, and frozen fish. The quantity of salted mackerel which is lost because of the rusting of the fat has been variously estimated at between 10 and 25 per cent of the entire pack. When one considers that the wholesale value of the mackerel salted annually in the United States alone is over a million dollars, it is not difficult to realize that this represents a very great loss to the American fishermen. Herring and alewives are even more difficult to keep than mackerel, and the losses are usually greater. Even fish containing but little fat such as the cod and haddock gradually turn yellow and harden. This yellowing is a sign of approaching rancidity because of changes in the fat similar to those causing rust. The writer[1] has pointed out that fish free from blood, salted with pure salt (free from calcium and magnesium salts) can be stored for much longer periods without rusting than fish salted by the usual commercial processes. This aids in the solution of the problem and indicates the probable cause of the trouble. Evidently certain enzymes contained in the blood hasten the chemical changes in the fat which become noticeable when the fish "rusts." Moreover, it must be concluded that the impurities in the salt also accelerate rusting. Oxygen is required for the development of rancidity. The storage of fish in such a way as to prevent the access of air would solve the problem.

Frozen fatty fish rust much more slowly than salted fish, yet if they are kept for long periods, especially if the temperature is allowed to rise, they rust badly. The solution of this problem is relatively simple. By merely lowering the temperature of the cold storage room and holding it constant, the danger of rusting is eliminated.

The prevention of the rusting of smoked fatty fish seems very difficult unless they are stored in air-tight containers. A thorough chemical and bacteriological investigation of the whole problem should be made; doubtless the quantity of fish saved in a single year would more than pay for the entire research.

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[1] *Fishing Gazette, 37,* No. 8, 1920, 10-11.

The scientific study of fish salting processes has indicated many improvements in the methods and quality of the products. No scientific studies of the changes taking place during the brining and smoking of fish have been made. Such researches would enable a more accurate control of the process and should point out means of improving the product. Radcliffe[2] in considering various problems of the fisheries says:

> The practice of preserving fish by smoking is very ancient and the products properly prepared may be numbered among the tastiest of foods. Yet how little attention has been given to the finesse of their preparation by trained technologists, how much of that offered for sale is only mediocre in quality. The varying composition of smoke from different fuels and at different temperatures, the penetration of the smoke, the subsequent fractional evaporation of the deposited smoke constituents from the fish, the possible addition of flavoring oils to the fuel, the coloring of the product, the prevention of mold on the smoked fish, possibilities of other improvements in keeping qualities, and in technique of preparation, all should be given careful study.

Various workers have recently developed new methods of dehydrating lean fish. The products seem excellent and promise to replace much of the dried salted fish on the market. The methods have received little commercial recognition as yet. Much advertizing will have to be done in order to familiarize the public with the products. The perfection of the proper equipment for fish dehydration on a large scale is an interesting engineering problem.

The fat in dehydrated fish, stored under ordinary conditions, becomes rancid quickly. Dehydrated fatty fish therefore cannot be stored for any considerable length of time. If fatty fish are to be dehydrated commercially, some one must discover an inexpensive way of storing the product satisfactorily.

Many difficult problems still stand in the way of the fish canner. However, this industry is particularly fortunate in having a number of excellent research chemists working towards the solution of the problems. A number of fish and fishery products such as the grayfish, develop ammonia in the can which attacks the tin and thus discolors the product. In the case of the grayfish the trouble is caused by the high content of urea in this fish. As yet no one has suggested an easy solution to this problem.

Sardines are fried by passing through cottonseed oil heated at 100 to 115° C. by immersed steam coils. Continued use of this oil causes it to become viscous, almost black in color, and to acquire a disagreeable taste and odor. The continual renewal of the oil is a source of great expense to the packers. Many attempts have been made to purify the offensive oil but these have met with little success. Beard[3] has recently conducted an investigation of the changes taking place in the oil during use and has concluded that the presence of varying quantities of fish oil, and the action of air and heat are largely responsible for the changes which take place. Beard has suggested the use of corn oil and hydrogenated cottonseed oil in addition to cottonseed oil as a possible remedy.

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[2] *Trans. Am. Fisheries Soc.*, *49* (1919), 3-18.
[3] *California Fish and Game Comm.*, Cir. 1 (1922).

In recent years many new fishery products have been canned. River herring, river herring roe and milt, many novel cod products, etc., were canned for the first time on a large scale during the World War when the demand for meat substitutes was great. The expansion in this field has only begun. Many other canned fish are equal in quality to salmon and tuna, and there is no reason why they should not be canned in large quantities. Canned marinated products would doubtless become popular with the public if a suitable advertising campaign were undertaken.

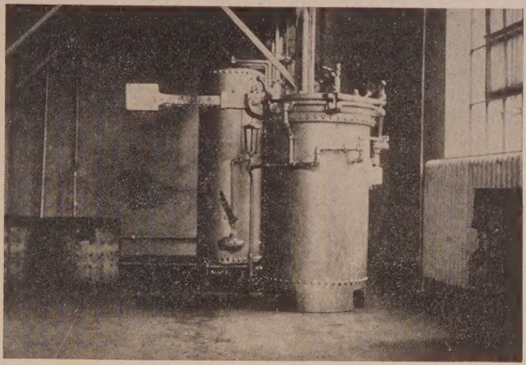

Fig. 254.—A portion of the experimental canning equipment of the U. S. Bureau of Fisheries' Fishery Products Laboratory.

During the recent period of high prices of linseed and other common paint and varnish oils, much fish oil was refined and used as a substitute for these better known oils. Many of the paints and varnishes, prepared with these substitute fish oils (menhaden, salmon, albacore, etc.), were found to be of equal or better quality than the original product. One well-known fishery concern has placed a complete line of paints and stains on the market which are prepared from fish oils that they manufacture. Excellent methods of decolorization and deodorization are being used. Unfortunately, these methods are either secret or patented and are not available to other manufacturers of fish oils. Much fish oil is hydrogenated or hardened and manufactured into soaps, and in Europe these hardened oils have been used as lard substitutes. Until recently there was no well-established market for fish oils other than menhaden, salmon, herring, and cod-liver oil. Now the values of sardine and albacore oils are being recognized. The properties of yellowtail fish oil have recently been studied by Gardner and Reilly.[4] This oil was found to be excellent for the manufacture of paints. The properties of many other fish oils should be studied. Doubtless if their properties were well known, a market for them would be found. The possibilities of fish oils are almost unlimited. Scientific research will discover uses so valuable that we will wonder why they were ever so cheap.

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[4] *Paint Mfgrs. Assoc., Educational Bureau,* Cir. 86 (1920).

Shark-liver oils have scarcely been investigated at all. In India and a few other countries they are used as medicinal oils. But no one has compared them with cod-liver oil. A study of their therapeutic properties should be made, with especial reference to their vitamin A content (see page 451). Tsujimoto and other Japanese oil chemists have carried out detailed researches concerning the chemical composition of the liver oils of many sharks caught in Japanese waters. These studies have indicated many uses for shark-liver oils that had scarcely been suspected. A new hydrocarbon, squalene, was discovered to be a component of many shark-liver oils, which possesses unusual properties. Similar studies of the liver oils of sharks caught in American waters should be conducted.

Means of obtaining concentrates of the vitamins and iodine compounds of cod-liver oil such as the trade product "gaduol" should be developed. The taking of a small dose of such a concentrate eliminates the necessity of taking large quantities of a medicine distasteful to many.

Another problem of the greatest commercial importance that has never been entirely solved is the construction of an apparatus by which small quantities of fish waste can economically be converted into animal feed, fertilizer, and oil. Professor John N. Cobb has estimated that fully one-fourth of the total weight of each salmon handled at the various packing plants on the Pacific Coast is thrown away. This means that about 100,000 tons of material which might be used for the manufacture of oil, feed, glue, and fertilizer is wasted annually in that region alone. A ton of salmon waste yields about 27 gallons of salmon oil, suitable for the manufacture of paints and varnishes and for other uses, and approximately 500 pounds of stock feed or fertilizer. It has been estimated that this salmon waste which is lost each year would yield from 2 to 5 million dollars' worth of by-products if properly utilized. Much of the waste is thrown into the harbor or river beneath the packing factory, where it putrefies and creates a public nuisance. Not only would there be a great saving but the public health would be benefited materially. There is also a very large waste of fish other than salmon which are taken in the same nets and traps. These are thrown overboard and practically all of them are killed and lost. In order to be used in the smaller canneries, the fertilizer equipment should not cost more than $2,500 to $3,000 and should be simple to operate. A portable plant which could be taken aboard a small steamer or schooner would be especially valuable, for this would permit the saving of the waste from the vast quantities of fish cleaned at sea.

Another great waste in the fishery industries is in the press water discarded by the menhaden oil and fertilizer industry. After cooking, the fish are pressed, thus separating the oil and water from the scrap. The oil is separated from the press water in large settling tanks after which the water usually is discarded. This involves a great loss as the press water contains nearly all of the glue formed during the cooking of the fish and much other protein in colloidal suspension. A satisfactory method of recovery of these constituents would save many thousands of dollars for the owners of these fertilizer factories.

The demand for high grade fish glue is much greater than the supply. Careful studies of the chemical composition of various fishes would doubtless disclose many new sources of glue stock. Salmon waste and menhaden press water contain much glue.

The tanning of shark skins on a large scale at one factory in North Carolina is a step in the right direction which eventually should lead to the organization of an important industry at many points along our southern coasts. According to reports there is an ample demand for the products. The trouble seems to lie in the difficulty of obtaining a sufficiently large, regular supply of sharks. There are other places along the coast where an abundant quantity of these destructive marine animals could be obtained.

FIG. 255.—The main building of the U. S. Bureau of Fisheries, Washington, D. C.

During the great shortage of meat in the World War, considerable quantities of whale meat were frozen and canned and sold as a substitute for beef steak. In 1918, 30,000 cases of whale meat were canned and 195 tons of frozen meat marketed. But when meat became plentiful once more, whale meat was again neglected and at present practically all of it is converted either into animal feed or fertilizer. The public should be convinced of the value of whale meat as food. Further studies of its nutritive value compared with beef should be made and the results widely published.

Vast quantities of loggerhead sponges exist along the coast of Florida. These sponges contain a high percentage of very pure silica in crystalline form. As yet no one has made any use of this silica or of the various by-products (e.g. iodine) obtained in its preparation.

A few of the major problems of the fishery industries have been outlined above. Why has so little been done towards solving problems of such great importance? The industry has not been organized to the extent that have most other large industries, it has not therefore been exploited as have the meat packing and related industries. Private individuals and small companies lack the funds and facilities for the prerequisite researches for the improvement of methods and utilization of by-products.

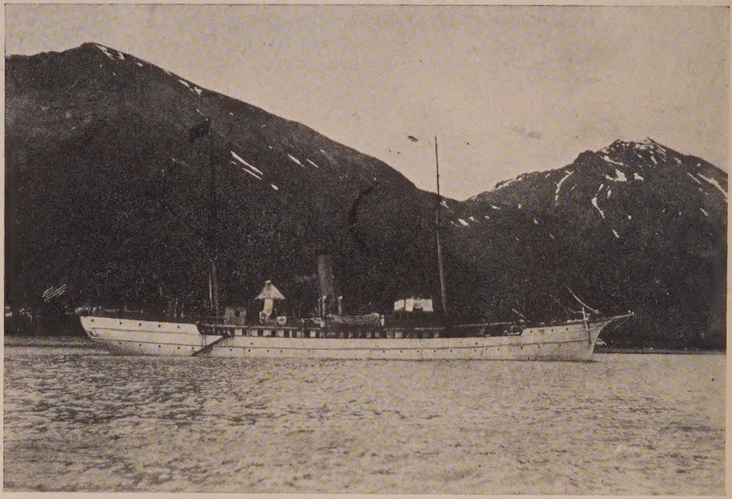

FIG. 256.—The Bureau of Fisheries steamer *Albatross*, employed in oceanographic investigations.

The logical place for much of this work is the Bureau of Fisheries. This institution, which gives the fishermen and the industries such valuable aid, has recently built a very fine fishery products laboratory for use in the solution of chemical and technological problems. Unfortunately, Congress has not seen fit to appropriate sufficient money to carry out the much needed investigations, therefore much of this equipment has remained idle.

Many of the fishermen and men of the industries have assumed an attitude which may well be criticized, for they seem to expect the government to do all the experimental work. If men in other industries waited for the various governmental bureaus to improve their processes, American industries would not progress rapidly. The National Canners Association might well be imitated by the American fishermen and fishery industries. For example an organization of fish oil, fertilizer and feed manufacturers could carry out scientific researches which would greatly increase the uses of fish oil and feed, and thereby increase the demand for these products.

Perhaps there is no single fish salting concern large enough to carry out the necessary chemical and bacteriological researches required for the solution of the problems of prevention of reddening of cod and other salted ground fish and the elimination of the danger of rusting of salted and smoked fatty fish. An association of packers could make these important investigations with only a small individual cost and derive mutual benefits therefrom. Many large manufacturers' associations have utilized the facilities of the Mellon Institute of Industrial Research of the University of Pittsburgh.

FIG. 257.—The laboratory of the Fish Products Fellowship, Mellon Institute of Industrial Research of the University of Pittsburgh, Pittsburgh, Pa.

Groups of well-trained scientists working towards a common end with every known facility at hand are almost certain to succeed in the solution of chemical problems if they are permitted sufficient time. Therein lies the secret of the success of the larger research institutions. The high degree of organization of America's industries and the increasing recognition of the value of research work by the captains of industry are responsible in a large measure for the rise of our great industries.

A rapid advance of the fishery industries cannot be expected until there is more coöperation among the fishery interests and a more general recognition of the value of scientific researches by the men controlling the organizations.

Science promises marvelous discoveries in new fields. Every year brings forth new wonders. Who can foresee what changes will come in the fisheries? The world moves rapidly forward, yesterday's apparent impossibilities are to-morrow's daily duties.

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APPENDIX I

1. STATISTICS OF THE FISHERIES OF THE UNITED STATES BY STATES *

COMPARATIVE STATISTICS OF THE PRODUCTS OF THE FISHERIES OF THE NEW ENGLAND STATES FOR VARIOUS YEARS FROM 1880 TO 1919.†

YEARS	MAINE		NEW HAMPSHIRE		MASSACHUSETTS		RHODE ISLAND		CONNECTICUT		TOTAL	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
1880	....	$2,742,571	....	$170,634	....	$7,959,760	....	$696,814	....	$933,242	....	$12,503,021
1887	131,379,591	2,364,906	4,254,727	99,460	299,544,343	6,464,396	45,284,872	683,495	39,750,008	300,746	520,213,541	9,913,003
1888	132,929,594	2,292,043	3,843,479	90,044	302,045,686	6,355,495	91,687,487	825,092	42,401,612	297,337	572,907,858	9,860,011
1889	129,559,864	2,111,206	4,354,568	88,511	299,217,669	5,858,274	127,365,475	935,144	92,672,464	1,557,506	653,170,040	10,550,641
1898	123,404,561	2,654,919	3,020,715	48,987	202,257,817	4,463,727	32,854,396	955,058	31,920,417	1,559,599	393,457,906	9,682,290
1902	242,390,371	2,918,772	1,593,013	50,003	230,645,950	6,482,427	21,613,964	1,155,701	37,832,149	1,799,381	534,075,447	12,406,284
1905	124,723,786	2,386,406	1,036,452	51,944	255,654,475	7,025,249	23,896,243	1,546,658	74,972,648	3,173,948	480,283,604	14,184,205
1908	173,843,000	3,257,000	677,000	53,000	244,313,000	7,095,000	44,254,000	1,752,000	66,942,000	2,982,000	530,029,000	15,139,000
1919	147,956,369	3,889,035	528,730	92,660	246,951,241	10,859,746	48,250,883	3,296,578	23,652,647	1,700,638	467,339,870	19,838,657

* Statistics for the coastal states are the only ones given here. The statistics for the freshwater fisheries are included; however ,in these states these fisheries are of minor importance.

† The statistics for 1908 in this table are from data published by the Bureau of the Census.

FISHERIES OF THE NEW ENGLAND STATES, 1919 *

ITEMS	MAINE		NEW HAMPSHIRE		MASSACHUSETTS		RHODE ISLAND		CONNECTICUT		TOTAL	
	Number	Value	Number	Value	Number	Value	Number	Value	Number	Value	Number	Value
PERSONS ENGAGED.												
On vessels fishing	1,004				4,459		317		566		6,346	
On vessels transporting	339		3		66		44		81		533	
In shore fisheries	5,332		85		3,737		795		1,019		10,968	
Shoresmen	7,711		12		4,084		490		623		12,920	
Total	14,386		100		12,346		1,646		2,289		30,767	
INVESTMENT.												
Vessels fishing, steam	5	$1,002,500			34	$2,484,545	9	$141,000	24	$328,243	72	$3,956,288
Tonnage	662				3,310		564		2,240		6,776	
Outfit		70,050				429,961		51,910		135,346		687,267
Vessels, fishing, gasoline	173	514,650			308	2,776,508	55	199,400	67	180,425	603	3,670,983
Tonnage	2,039				8,202		849		924		12,014	
Outfit		91,013				1,059,438		82,025		94,690		1,327,166
Vessels, fishing, sail	4	53,000			54	808,315			24	12,495	82	873,810
Tonnage	392				4,734				183		5,309	
Outfit		25,800				352,312				7,955		386,067
Vessels, transporting, steam	2	9,000					5	22,000	2	13,200	9	44,200
Tonnage	28						77		111		216	
Outfit		2,800						23,800		9,627		36,227
Vessels, transporting, gasoline	165	510,040	1	$6,300	22	108,950	13	29,200	4	7,800	205	662,290
Tonnage	1,762		8		460		104		95		2,429	
Outfit		103,998		3,000		16,680		10,500		4,370		138,548
Vessels, transporting, sail	2	16,715			3	13,800					5	30,515
Tonnage	121				132						253	
Outfit		6,375				2,375						8,750
Vessels, transporting, barge									2	4,000	2	4,000
Tonnage									316		316	
Outfit										1,900		1,900
Boats, sail, row, etc	2,759	83,639	31	802	1,308	58,488	196	4,503	399	9,670	4,693	157,102
Boats, power	3,090	902,080	53	10,675	1,732	891,195	432	182,780	364	136,881	5,671	2,123,611
Apparatus, vessel fisheries:												
Seines	84	93,270			100	193,850	18	24,695	4	7,800	206	319,615
Gill nets	1,253	29,689			5,430	107,685	780	14,445	115	2,680	7,578	154,499
Pound nets							25	75,000			25	75,000

Otter trawls	13	2,520			119	17,850	20	973	14	680	166	22,023
Lines, hand and trawl		34,747				133,658		785		555		169,745
Harpoons		2,230				6,655		561		600		10,046
Lobster pots	1,085	2,195			430	1,050	635	1,985	480	745	2,630	5,975
Dredges	4	400			224	2,516	48	2,092	372	8,437	648	13,445
Tongs and rakes					3	49					3	49
Whaling apparatus						29,000						29,000
Apparatus, shore fisheries:												
Seines	103	44,055			67	46,045	11	899	54	4,893	235	95,892
Gill nets	2,786	71,214			3,688	77,323	360	7,300	204	13,910	7,038	169,747
Pound nets, trap nets, and weirs	690	514,665			254	387,470	108	101,750	42	9,112	1,094	1,012,997
Fyke nets	146	3,685			53	1,585	290	5,218	439	3,985	928	14,473
Bag nets and pocket nets	95	8,675									95	8,675
Bow nets					13	36					13	36
Dip nets and scoop nets	102	776			104	374	30	450	7	35	243	1,635
Otter trawls	39	1,635			191	9,510	43	2,425	53	2,394	326	15,964
Lines, hand and trawl		61,410		462		51,412		4,492		58		117,834
Harpoons		215				540		690		80		1,525
Spears	42	57			72	171			30	39	144	267
Cunner traps	80	140			4	6					84	146
Eel pots and traps	599	1,198	18	36	1,826	4,455	995	1,035	801	617	4,239	7,341
Lobster pots	153,532	382,258	2,275	6,735	43,012	109,359	21,936	65,346	16,173	42,534	236,928	606,232
Crab traps	180	330									180	330
Dredges	24	2,500			2,764	16,521	201	1,119	55	395	3,044	20,535
Tongs and grabs					235	1,355	247	1,999	244	1,994	726	5,348
Rakes			2	12	784	5,656	29	166	61	367	876	6,201
Forks and hoes	1,103	1,167	25	50	475	887	152	148	68	69	1,823	2,321
Shovels							43	43	13	13	56	56
Cockle traps					680	500					680	500
Winkle pots							260	880			260	880
Shore and accessory property		11,864,571		11,958		7,000,239		978,622		498,699		20,354,089
Cash capital		1,029,707		5,500		1,902,945		209,300		98,500		3,245,952
Total		$17,544,969		$45,530		$19,111,269		$2,249,536		$1,645,793		$40,597,097

* From Bureau Fisheries, Statistical Bull. 497

PRODUCTS	MAINE		NEW HAMPSHIRE		MASSACHUSETTS		RHODE ISLAND		CONNECTICUT		TOTAL	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Valuc
Alewives, fresh	580,811	$7,455	......	......	1,097,476	$23,070	269,565	$5,916	177,150	$6,637	2,125,002	$43,078
Alewives, salted	6,860	176	......	......	1,259,134	55,995	......	......	......	......	1,265,994	56,171
Alewives, smoked	352,293	19,606	......	......	39,000	2,845	......	......	......	......	391,293	22,451
Bluefish	39	7	......	......	4,721	791	25,675	3,170	3,710	386	34,145	4,354
Bonito	44	4	......	......	189,727	18,018	114,810	10,825	6,120	912	310,701	29,759
Bullheads	......	......	......	......	......	......	......	......	1,492	100	1,492	100
Butterfish	32,763	3,031	......	......	296,828	26,810	758,845	39,188	18,810	2,607	1,107,246	71,636
Carp	......	......	......	......	......	......	......	......	40,141	4,922	40,141	4,922
Cod, fresh	13,095,145	479,827	98,354	$3,609	66,320,920	2,826,091	1,148,331	49,747	96,136	9,603	80,758,886	3,368,877
Cod, salted	983,244	62,312	......	......	3,175,405	166,702	......	......	......	......	4,158,649	229,014
Cunner	30,695	615	......	......	9,959	585	8,000	960	......	......	48,654	2,160
Cusk, fresh	1,046,147	33,580	2,400	86	1,561,337	55,068	......	......	6,767	73	2,616,651	88,807
Cusk, salted	......	......	......	......	16,870	759	......	......	......	......	16,870	759
Eels	305,050	25,249	2,000	240	374,167	47,714	274,735	29,637	63,046	9,839	1,018,998	112,679
Flounders	469,594	22,227	8,000	240	10,262,693	478,850	2,451,579	79,567	2,349,181	91,962	15,541,047	672,846
Grayfish	......	......	......	......	63,667	184	......	......	......	......	63,667	184
Goosefish or monkfish	......	......	......	......	2,500	7	......	......	......	......	2,500	7
Haddock, fresh	11,124,411	332,215	18,764	829	77,804,810	2,191,215	10,300	512	350	38	88,958,635	2,524,809
Haddock, salted	73,400	2,812	......	......	373,574	16,996	......	......	......	......	446,974	19,808
Hake, fresh	16,108,575	329,227	3,000	98	4,066,437	156,353	......	......	10,100	102	20,188,112	485,780
Hake, salted	5,060	256	......	......	29,095	1,307	......	......	......	......	34,155	1,563
Halibut, fresh	217,476	31,841	......	......	1,708,509	296,232	......	......	25,000	5,000	1,950,985	333,073
Halibut, salted	1,000	80	......	......	8,045	1,060	......	......	......	......	9,045	1,140
Herring, fresh	86,646,126	455,604	......	......	10,811,409	129,408	169,660	4,010	3,000	71	97,630,195	589,093
Herring, salted	6,200	187	......	......	......	......	......	......	......	......	6,200	187
Herring, smoked	161,550	6,715	......	......	......	......	......	......	......	......	161,550	6,715
Hickory shad	......	......	......	......	12,800	830	......	......	......	......	12,800	830
King whiting	......	......	......	......	72	18	......	......	......	......	72	18
Launce	......	......	......	......	67,800	838	......	......	......	......	67,800	838
Mackerel, fresh	593,506	81,428	......	......	12,267,132	1,212,461	1,575,923	146,611	91,389	10,990	14,527,950	1,451,490
Mackerel, salted	8,000	650	......	......	1,249,062	109,948	......	......	......	......	1,257,062	110,598
Mackerel, frigate	......	......	......	......	61,361	1,862	......	......	......	......	61,361	1,862
Menhaden	......	......	......	......	161,219	2,231	21,536,000	268,700	6,736,564	93,312	28,433,783	364,243
Minnows	......	......	......	......	1,000	125	......	......	......	......	1,000	125
Perch, white	......	......	......	......	6,200	920	5,043	702	......	......	11,243	1,622
Perch, yellow	......	......	......	......	500	25	......	......	6,108	595	6,608	620
Pickerel	......	......	......	......	......	......	......	......	1,079	143	1,079	143
Pollack, fresh	5,597,163	113,487	25,600	615	19,192,388	468,169	99,400	5,920	10,135	717	24,924,686	588,908
Pollack, salted	34,800	2,440	......	......	50,153	1,774	......	......	......	......	84,953	4,214
Pompano	......	......	......	......	14	2	......	......	......	......	14	2
Rosefish	17,322	245	......	......	36,773	1,124	......	......	......	......	54,095	1,369
Round herring	......	......	......	......	941	19	......	......	......	......	941	19
Salmon, Atlantic	20,610	7,926	......	......	......	......	70	12	......	......	20,680	7,938
Salmon, humpback	310	62	......	......	......	......	......	......	......	......	310	62
Sculpin	......	......	......	......	6,000	15	......	......	......	......	6,000	15
Scup	......	......	......	......	78,624	5,666	8,261,140	817,846	1,980	202	8,341,744	823,714
Sea bass	......	......	......	......	15,067	1,649	52,041	5,954	3,555	528	70,663	8,131
Sea robin	......	......	......	......	400	1	......	......	......	......	400	1

Shad	414,455	28,393			62,337	4,309			463,203	86,637	939,995	119,339
Sharks	39,747	884			328,399	3,664					368,146	4,548
Skates and rays	2,385	47			100,354	503			400	10	103,139	560
Smelt	523,967	94,496			39,150	10,690			25,217	4,466	588,334	109,652
Squeteague					5,777	908	353,860	33,829	23,076	3,257	382,713	37,994
Striped bass	592	113			971	231	33,705	5,236	4,810	1,059	40,078	6,639
Sturgeon	8,129	1,714			12,098	3,358			25	5	20,252	5,077
Sturgeon caviar					150	356					150	356
Sturgeon roe	143	297			181	163					324	460
Suckers	110,400	11,852							99,053	7,488	209,453	19,340
Sunfish									105	11	105	11
Swordfish	424,813	104,734			711,729	155,330	101,010	19,757	88,428	15,006	1,325,980	294,827
Tautog	14	2			91,876	8,885	371,660	22,191	21,942	2,068	485,492	33,146
Tilefish					188,180	9,803					188,180	9,803
Tomcod	147,160	4,511			7,890	239			455	37	155,505	4,787
Tuna	31,909	2,040			42,901	3,548	61,350	4,810	5,114	550	141,274	10,948
Whiting, fresh	684,970	4,727			13,918,650	148,854	1,583,700	16,010	9,317	175	16,196,637	169,766
Whiting, salted	3,000	90									3,000	90
Wolffish	83,958	2,061			291,188	9,219					375,146	11,280
Other fish					38,232	2,117					38,232	2,117
Lobster	5,545,884	1,411,548	298,012	73,203	2,387,636	516,393	1,694,327	360,679	740,848	189,157	10,666,707	2,550,980
Shrimp					3,400	1,589					3,400	1,589
Crabs, hard	70,575	3,595			1,764,961	49,424	34,330	1,802			[1] 1,869,866	54,821
Crabs, soft					266	40					[2] 266	40
Squid	377	4			6,134,557	108,864	377,579	18,730	3,612	258	6,516,125	127,856
Clams, hard, public					853,304	271,342	156,232	59,649	49,976	18,912	[3] 1,059,512	349,903
Clams, hard, private					22,640	12,425					[4] 22,640	12,425
Clams, soft, public	2,105,734	163,209	66,600	13,320	2,062,630	232,194	403,760	24,075	229,150	32,070	[5] 4,867,874	464,868
Clams, soft, private					125,000	10,750					[6] 125,000	10,750
Clams, razor					23,300	3,500					[7] 23,300	3,500
Oysters, market, public					5,579	1,383			136,654	21,900	[8] 142,233	23,283
Oysters, market, private					769,055	278,164	6,261,759	1,242,585	4,826,668	471,766	[9] 11,857,482	1,992,515
Oysters, seed, public					23,100	1,320			740,516	68,349	[10] 763,616	69,669
Oysters, seed, private					80,178	6,552			6,493,865	525,001	[11] 6,574,043	531,553
Scallops	72,512	31,416			1,332,486	439,382	33,994	14,608	38,400	13,717	[12] 1,477,392	499,123
Mussels	16,970	367					10,000	1,000			[13] 26,970	1,367
Cockles and winkles					577,400	3,425	10,500	2,100			[14] 587,900	5,525
Blackfish					40,000	40					40,000	40
Porpoise					750	15					750	15
Livers	112,587	1,712			313,575	4,844					426,162	6,556
Spawn	18,857	778			146,929	8,836					165,786	9,614
Tongues and cheeks	5,200	190			600	12					5,800	202
Sounds	5,212	96									5,212	96
Oil, sperm					1,545,413	218,111					[15] 1,545,413	218,111
Oil, liver	8,625	895									[16] 8,625	895
Ambergris					30	5,000					30	5,000
Alewife scales					10,400	5,200					10,400	5,200
Irish moss			6,000	420	204,200	15,027	2,000	240			212,200	15,687
Total	147,956,369	$3,889,035	528,730	$92,660	246,951,241	$10,859,746	48,250,883	$3,296,578	23,652,647	$1,700,638	467,339,870	$19,838,657

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[1] 5,609,598 in number. [2] 798 in number. [3] 132,439 bushels. [4] 2,830 bushels. [5] 486,787 bushels. [6] 12,500 bushels. [7] 2,330 bushels. [8] 20,319 bushels. [9] 1,693,926 bushels. [10] 109,088 bushels. [11] 939,149 bushels. [12] 246,232 bushels. [13] 2,697 bushels. [14] 58,790 bushels. [15] 206,055 gallons. [16] 1,150 gallons.

FISHERIES OF NEW YORK, NEW JERSEY, PENNSYLVANIA, AND DELAWARE, 1921.*

ITEMS	NEW YORK		NEW JERSEY		PENNSYLVANIA		DELAWARE	
	Number	Value	Number	Value	Number	Value	Number	Value
PERSONS ENGAGED.								
On vessels fishing	1,799		2,164		42		279	
On vessels transporting	62		28		2		2	
In shore fisheries	2,365		2,982		105		540	
Shoresmen	2,919		597		442		155	
Total	7,145		5,771		591		976	
INVESTMENT.								
Vessels, fishing, steam	31	$3,270,000					4	$165,382
Tonnage	1,555						492	
Outfit		242,057						7,591
Vessels, fishing, gasoline	229	791,515	215	$830,100	3	$26,000	12	38,900
Tonnage	2,775		2,493		93		135	
Outfit		240,859		203,940		5,050		9,050
Vessels, fishing, sail	7	5,150	127	300,600			13	26,200
Tonnage	55		1,818				133	
Outfit		1,525		56,295				6,920
Vessels, transporting, steam	2	13,000						
Tonnage	41							
Outfit		2,380						
Vessels, transporting, gasoline	48	182,300	24	49,500			1	600
Tonnage	733		252				7	
Outfit		30,249		2,175				
Vessels, transporting, sail	2	13,500	4	850	1	800	3	2,000
Tonnage	103		27		10		21	
Outfit		1,100				75		100
Boats, sail, row, etc	1,249	61,005	1,135	36,759	37	1,205	303	7,770
Boats, power, etc	838	443,980	1,551	647,920	8	3,100	113	31,265
Apparatus, vessel fisheries:								
Purse seines	37	86,600	20	23,000	1	1,000	4	6,000
Gill nets	26	2,375	991	17,165				
Pound nets	8	27,000	82	315,850				
Fyke nets	180	960						
Drag nets	2	15						
Otter trawls	46	3,655	23	1,630				
Lines, hand, trawl and set		4,710		1,296		250		
Harpoons		150						
Eel pots	150	300	50	125				
Lobster pots	1,175	2,543	350	450				
Dredges	848	11,302	520	10,605			4	90
Tongs, rakes, etc	122	995	62	630				
Apparatus, shore fisheries:								
Pound nets, floating traps, and weirs	414	163,285	217	135,220			5	1,000
Gill nets	918	52,442	3,657	100,742	13	1,370	156	6,930
Fyke nets	2,757	22,235	1,285	9,530	25	35	431	1,629
Haul seines	155	14,185	184	13,550	22	1,912	93	9,000
Purse seines			1	600				
Drag nets	30	192						
Scap nets	138	3,281						
Dip nets	22	25						
Stop nets	14	1,405	86	12,365	5	625		
Bag nets			58	1,160				
Otter trawls	50	3,140	8	540				
Lines, hand and trawl		4,678		5,023				25
Eel pots	3,780	8,537	4,102	4,632			101	101
Lobster pots	13,363	33,700	10,345	10,944			180	180
Harpoons		185						
Spears	46	224						
Dredges	1,236	7,838	52	775				
Tongs, rakes, and hoes	765	5,088	1,321	6,728			208	1,040
Other apparatus		93		143				888
Shore and accessory property		7,140,497		1,587,762		1,074,156		153,400
Cash capital		936,200		313,100		260,200		108,500
Total		$13,836,455		$4,701,704		$1,375,778		$584,561

* From Bureau Fisheries Statistical Bull. 569.

PRODUCTS	New York		New Jersey		Pennsylvania		Delaware	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
Albacore	29,354	$1,420	125,642	$3,985	....	....	....	....
Alewives	377,793	11,283	408,193	11,914	20,085	$405	351,590	$6,431
Bluefish	1,082,917	176,726	2,243,425	390,947	600	108	1,325	265
Bonito	255,887	30,350	1,503,253	91,046	....	....	....	....
Butterfish	630,076	64,109	2,862,491	159,286	200	6	....	....
Carp	421,642	63,678	329,555	53,184	9,712	1,511	87,820	13,166
Catfish	43,435	6,722	101,067	5,976	2,125	128	35,291	2,574
Cod	667,860	37,783	687,277	37,353	....	....	....	....
Croaker	....	....	3,815,554	126,700	2,400	48	418,873	18,682
Drum, black	....	....	67,659	1,365	....	....	1,150	22
Drum, red	....	....	500	10	....	....	....	....
Eels, fresh	463,552	58,008	274,754	26,450	220	22	16,012	1,598
Eels, smoked	....	....	4,680	1,497	....	....	....	....
Flounders	4,471,161	283,412	1,985,340	140,586	200	10	34,429	1,798
Gizzard shad	....	....	....	....	....	....	7,320	292
Haddock	18,515	876	6,300	338	....	....	....	....
Hake	35,906	1,430	821,018	25,563	....	....	....	....
Herring	6,575	206	172,732	4,464	....	....	....	....
Hickory shad	23,455	1,444	28,145	1,582	....	....	....	....
Hogfish	....	....	....	....	2,000	80	....	....
Kingfish	70,447	13,589	24,119	3,334	....	....	....	....
Mackerel	282,075	40,356	584,386	100,556	....	....	....	....
Menhaden	179,447,799	1,117,235	30,405,093	121,451	....	....	18,082,000	67,970
Mullet, fresh	1,250	85	18,460	1,136	....	....	513	25
Mullet, salted	....	....	1,200	240	....	....	....	....
Perch, white	64,041	7,578	130,970	18,791	....	....	6,923	922
Perch, yellow	25,500	2,896	31,282	4,708	....	....	2,758	273
Pike or pickerel	215	48	500	100	....	....	272	25
Pollack	84,300	2,325	4,540	127	....	....	....	....
Pompano	35	7	....	....	....	....	....	....
Scup or porgy	1,297,375	76,253	4,115,552	200,046	142,000	7,100	....	....
Sea bass	148,434	21,412	1,378,330	86,823	135,000	12,500	250	12
Sea robin	38,419	1,140	63,640	1,340	....	....	....	....
Shad	115,692	27,128	168,637	44,460	18,872	5,834	86,836	16,312
Sharks	10,659	284	60,459	1,232	....	....	....	....
Skates and rays	75,550	1,149	43,100	1,186	....	....	....	....
Smelt	6,200	1,185	450	335	....	....	....	....
Spanish mackerel	25	5	3,982	979	....	....	....	....
Spot	43,757	3,728	189,548	11,502	....	....	14,600	928
Squeteagues, or weakfish	1,921,036	228,524	11,651,735	902,439	240,000	14,400	886,550	53,317
Striped bass	94,525	18,662	70,348	21,691	....	....	4,915	1,426
Sturgeon	33,917	9,199	45,825	7,120	....	....	12,090	1,813
Sturgeon caviar	940	1,706	74	194	....	....	....	....
Sturgeon roe	....	....	3,572	10,746	....	....	1,872	5,139
Suckers	132,618	16,731	50,664	5,139	21,199	2,469	983	118
Swordfish	44,865	9,125	....	....	....	....	....	....
Tautog	54,722	4,362	44,043	2,650	....	....	1,500	75
Tilefish	1,133,000	76,984	....	....	....	....	....	....
Tomcod	57,200	2,083	1,950	97	....	....	....	....
Tuna	32,413	2,745	87,734	3,493	....	....	....	....
Whitebait	13,561	1,335	....	....	....	....	....	....
Whiting	939,287	12,212	3,280,833	64,371	....	....	....	....
Other fish	171,240	7,652	789	34	....	....	....	....
Lobster	1,037,595	196,762	397,841	88,588	....	....	10,400	2,600
Shrimp	88,450	28,890	20,000	400	....	....	....	....
Crabs, hard	477,242	17,807	119,244	7,290	....	....	....	....
Crabs, soft	5,885	1,855	16,800	6,132	....	....	4,600	1,150
Crabs, king	750	11	3,313,174	10,416	....	....	630,000	1,890
Squid	330,117	18,500	433,902	20,008	....	....	....	....
Clams, hard, public	764,824	214,528	782,088	364,548	....	....	4,040	2,340
Clams, hard, private	5,400	1,950	....	....	....	....	....	....
Clams, soft, public	186,150	32,670	143,500	20,650	....	....	....	....
Clams, soft, private	2,000	325	....	....	....	....	....	....
Skimmers, or surf clams	48,160	11,300	....	....	....	....	....	....
Mussels	50,000	2,500	791,000	6,070	....	....	....	....
Oysters, market, public	292,453	41,790	69,300	10,190	....	....	870,219	74,140
Oysters, market, private	9,131,017	1,733,663	10,977,855	2,060,306	....	....	1,942,563	293,975
Oysters, seed, public	69,825	9,710	11,638,900	666,905	....	....	1,502,949	82,758
Oysters, seed, private	7,000	750	311,500	22,529	....	....	....	....
Scallops	1,235,760	217,108	540	90	....	....	....	....
Turtles	800	19	13,715	334	....	....	2,250	112
Terrapin	600	350	225	225	....	....	300	300
Shells	1,760,000	1,480	....	....	....	....	....	....
Miscellaneous products	14,099	9,780	7,800	159	....	....	....	....
Total	210,377,152	$4,986,918	96,936,784	$5,983,406	594,613	$44,621	25,023,193	$652,448

Note.—The above statistics do not include any fisheries of the Great Lakes or other inland waters.

FISHERIES OF MARYLAND AND VIRGINIA, 1920.*

ITEMS	Maryland		Virginia	
	Number	Value	Number	Value
PERSONS ENGAGED				
On vessels fishing	1,947	....	1,995	....
On vessels transporting	733	....	563	....
In shore fisheries	9,859	....	11,612	....
Shoresmen	8,844	....	5,208	....
Total	21,383	....	19,378	....
INVESTMENT				
Vessels, fishing, steam	....	....	45	$2,232,025
Tonnage	....	....	4,718	....
Outfit	....	....	....	486,561
Vessels, fishing, gasoline	14	$11,050	81	456,975
Tonnage	197	....	1,150	....
Outfit	....	2,860	....	108,523
Vessels, fishing, sail	402	451,385	44	29,350
Tonnage	4,133	....	354	....
Outfit	....	95,817	....	14,572
Vessels, transporting, gasoline	124	231,200	222	375,450
Tonnage	1,479	....	2,125	....
Outfit	....	44,562	....	80,752
Vessels, transporting, sail	184	352,275	56	128,900
Tonnage	5,131	....	1,536	....
Outfit	....	41,348	....	13,660
Boats, sail, row, etc	3,264	197,508	5,476	194,136
Boats, power	3,128	958,598	3,404	994,000
Apparatus, vessel fisheries:				
Purse seines	3	900	50	121,800
Haul seines	....	....	1	150
Crab scrapes	91	636	24	172
Crab dredges	....	....	62	2,450
Oyster dredges	856	19,728	201	4,470
Tongs	28	382	22	276
Apparatus, shore fisheries:				
Purse seines	1	200	....	....
Haul seines	218	24,836	196	41,505
Gill nets	4,247	86,176	15,152	98,108
Pound nets and weirs	1,072	390,285	1,882	895,762
Trammel nets	5	533	....	....
Fyke nets	3,868	29,827	1,301	24,092
Bow nets	37	346	....	....
Dip nets	1,305	1,389	867	560
Stop nets	2	125	4	120
Otter trawls	1	95	1	125
Lines, hand and trot	....	9,399	....	8,847
Slat traps or baskets	1	100	40	600
Eel pots	4,226	4,128	562	1,132
Eel spears	9	21	2	10
Crab traps	....	....	13	18
Crab scrapes	1,396	9,774	531	3,784
Crab dredges	....	....	56	1,056
Oyster dredges	547	13,067	217	3,610
Scallop dredges	....	....	304	2,244
Tongs, nippers, rakes, and hoes	6,006	44,628	5,421	45,000
Shore and accessory property	....	3,589,956	....	3,561,449
Cash capital	....	953,300	....	777,255
Total	....	$7,566,434	....	$10,709,499

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* From Bureau Fisheries Statistical Bull. 520.

FISHERIES OF MARYLAND AND VIRGINIA, 1920—*Continued*

PRODUCTS	MARYLAND		VIRGINIA	
	Pounds	Value	Pounds	Value
Alewives, fresh	5,647,388	$114,470	16,635,100	$258,358
Alewives, salted	1,426,300	62,770	30,000	900
Black bass	77,388	18,969	342,500	44,525
Black drum	700	8	59,980	792
Bluefish	73,595	16,764	178,475	27,211
Bonito	46,420	2,785	183,535	13,358
Butterfish	875,827	24,302	3,018,842	136,894
Carp	329,450	22,925	282,695	20,559
Catfish	471,207	29,367	826,485	48,383
Crevalle	3,200	96	760,448	24,378
Croaker	2,519,770	66,576	16,372,134	513,975
Eels, fresh	170,118	18,936	121,800	12,559
Eels, salted	31,450	3,145	....	....
Flounders	287,765	15,078	313,584	15,715
Gizzard shad	30,067	913	139,355	4,723
Goldfish	500	38	4,050	380
Hickory shad	2,100	95	163,950	6,047
King whiting	9,190	1,741	40,222	3,411
Mackerel	....	....	70,677	8,473
Menhaden	7,500	30	366,379,425	2,158,518
Mullet	101,357	5,162	458,158	17,417
Ocean sunfish	....	....	100	20
Perch, white	321,739	32,991	648,165	46,638
Perch, yellow	310,398	31,452	117,755	10,547
Pigfish	....	....	69,300	3,523
Pike or pickerel	64,458	13,688	80,860	8,081
Pompano	734	147	6,930	1,430
Redfish or red drum	41,535	627	117,550	3,753
Scup	101,980	2,611	35,140	2,418
Sea bass	42,980	3,447	18,975	1,427
Shad	1,867,196	355,217	7,293,805	1,145,106
Sheepshead	51	8	2,155	263
Spanish mackerel	8,477	1,282	33,839	5,039
Spot	364,759	6,829	967,296	67,270
Squeteagues, or "sea trout":				
Fresh	2,274,490	91,514	12,908,502	654,521
Salted	7,000	770	....	....
Striped bass	1,040,274	193,295	379,568	68,858
Sturgeon	21,411	5,551	78,388	14,368
Sturgeon caviar	2,784	8,750	5,172	16,038
Sturgeon roe	....	....	101	150
Suckers	2,000	160	2,800	85
Sunfish	5,300	70	....	....
Whiting	11,730	234	....	....
Yellowtail or "silverperch"	400	40	3,350	126
Crabs, hard	[1] 5,165,703	248,160	[2] 12,465,342	401,295
Crabs, soft	[3] 3,897,271	494,784	[4] 1,171,737	164,269
Squid	468	29	42,150	1,475
Clams, hard	[5] 30,200	10,575	[6] 499,440	229,645
Oysters, market, public	[7] 29,953,581	2,111,345	[8] 10,757,488	993,548
Oysters, market, private	[9] 1,878,716	179,775	[10] 11,823,420	1,174,375
Oysters, seed, public	....	....	[11] 5,008,150	178,038
Oysters, seed, private	....	....	[12] 155,925	3,200
Scallops	....	....	[13] 113,760	26,852
Terrapin	823	1,000	248	360
Turtles	3,045	147	18,680	1,165
Frogs	....	....	480	120
Cabomba	....	....	900	90
Alewife scales	....	....	10,203	1,055
Total	59,530,795	$4,198,668	471,219,089	$8,541,724

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[1] 15,497,109 in number. [2] 37,396,026 in number. [3] 11,691,813 in number. [4] 3,515,211 in number. [5] 3,775 bushels. [6] 62,430 bushels. [7] 4,279,083 bushels. [8] 1,536,784 bushels. [9] 268,388 bushels. [10] 1,689,060 bushels. [11] 715,450 bushels. [12] 22,275 bushels. [13] 18,960 bushels.

FISHERIES OF THE SOUTH ATLANTIC STATES, 1918.*

ITEMS	NORTH CAROLINA		SOUTH CAROLINA		GEORGIA		FLORIDA(EAST COAST ONLY)		TOTAL	
	Number	Value	Number	Value	Number	Value	Number	Value	Number	Value
PERSONS ENGAGED.										
On vessels fishing	1,295	....	103	....	186	....	380	....	1,964	....
On vessels transporting	54	....	20	....	2	....	15	....	91	....
In shore fisheries	4,903	....	1,121	....	476	....	2,104	....	8,604	....
Shoresmen	1,784	....	756	....	1,016	....	831	....	4,387	....
Total	8,036	....	2,000	....	1,680	....	3,330	....	15,046	....
INVESTMENT.										
Vessels fishing:										
Steam	15	$807,315	....	....	....	....	....	....	15	$807,315
Tonnage	1,791	....	....	....	....	....	....	....	1,791	....
Outfit	....	246,685	....	....	....	....	....	....	....	246,685
Gasoline	55	413,710	3	$7,005	27	$119,848	23	$377,600	108	918,163
Tonnage	1,258	....	74	....	499	....	725	....	2,556	....
Outfit	....	166,360	....	2,075	....	41,416	....	71,287	....	281,138
Sail	48	28,700	33	20,995	5	2,315	....	....	86	52,010
Tonnage	388	....	357	....	44	....	....	....	789	....
Outfit	....	9,745	....	4,415	....	325	....	....	....	14,485
Vessels transporting:										
Gasoline	25	24,600	7	11,000	1	500	7	32,300	40	68,400
Tonnage	197	....	74	....	9	....	89	....	369	....
Outfit	....	13,775	....	1,350	....	125	....	3,850	....	19,100
Sail	12	9,700	....	....	....	....	....	....	12	9,700
Tonnage	92	....	....	....	....	....	....	....	92	....
Outfit	....	4,450	....	....	....	....	....	....	....	4,450
Boats, sail, row, etc	1,727	38,053	639	15,810	313	8,805	607	20,180	3,286	82,848
Boats, power	1,357	269,720	51	20,600	99	77,400	839	459,650	2,346	827,370
Apparatus, vessel fisheries:										
Purse seines	57	156,727	....	....	4	4,800	25	52,900	86	214,427
Gill nets	13	800	....	....	....	....	....	....	13	800
Lines	....	50	....	100	....	105	....	....	....	255
Otter trawls	2	100	....	....	12	705	....	....	14	805
Dredges	86	2,655	....	....	6	300	....	....	92	2,955
Tongs and grabs	22	100	165	527	42	160	....	....	229	787

Apparatus, shore fisheries:										
Purse seines	3	1,600					2	3,000	5	4,600
Haul seines	440	41,533	25	2,550	2	80	115	58,030	582	102,193
Gill nets	14,299	108,878	233	16,525	139	5,955	715	101,725	15,386	233,083
Pound nets	3,779	355,439							3,779	355,439
Fyke nets	591	6,230							591	6,230
Cast nets			71	155	1	3	16	80	88	238
Stop nets	6	90	2	130					8	220
Lines		333		515		13		2,965		3,826
Otter trawls	27	960	2	90	73	3,700	255	16,500	357	21,250
Eel pots	1,585	1,329							1,585	1,329
Dredges	550	2,648							550	2,648
Tongs, grabs, and rakes	1,008	2,046	549	1,482	400	1,264	37	224	1,994	5,016
Spears or gigs	80	78	36	27			12	12	128	117
Crab traps and drags	113	565					20	50	133	615
Other apparatus		375		25				6		406
Shore and accessory property		1,347,644		95,775		429,779		858,720		2,731,918
Cash capital		159,050		20,100		72,400		151,600		403,150
Total		$4,222,043		$221,251		$769,998		$2,210,679		$7,423,971

* From Bureau Fisheries Statistical Bull. 494.

FISHERIES OF THE SOUTH ATLANTIC STATES, 1918.—*Continued*

PRODUCTS	NORTH CAROLINA		SOUTH CAROLINA		GEORGIA		FLORIDA (EAST COAST ONLY)		TOTAL	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
Alewives:										
Fresh	8,739,944	$238,624	9,500	$475			692,265	$10,373	9,441,709	$249,472
Salted	5,743,876	162,595							5,743,876	162,595
Amberfish							11,686	390	11,686	390
Angelfish	8,975	340					2,915	91	11,890	431
Barracuda							2,915	97	2,915	97
Black bass	551,125	63,137							551,125	63,137
Bluefish	322,744	29,677	3,000	275	5,000	$900	561,301	54,715	892,045	85,567
Blue runner or hardtail							50,750	1,542	50,750	1,542
Bonito	3,015	107					8,141	258	11,156	365
Bowfin	34,372	319							34,372	319
Butterfish	731,257	24,785	600	45			4,200	170	736,057	25,000
Carp	153,169	5,619							153,169	5,619
Catfish	304,509	9,783	2,900	108	2,675	265	13,900	278	323,984	10,434
Cero and Kingfish	211,781	13,947			74	7	2,271,792	147,608	2,483,647	161,562
Cowfish and "shellfish"							50	2	50	6
Crappie	5,340	568							5,340	528
Crevalle	204	11	300	65			321,030	9,833	321,534	9,909
Croaker	386,807	11,912	16,000	1,062	5,900	255	124,278	3,447	532,985	16,676
Drum, red and black	99,546	3,246	6,000	285	1,674	112	900,091	24,638	1,007,311	28,281
Eels	174,541	13,333							174,541	13,333
Flounders	91,121	7,022	16,200	1,061	10,800	650	13,490	737	131,611	9,470
Gizzard shad	44,525	1,154							44,525	1,154
Groupers					27,758	1,019	74,783	3,622	102,541	4,641
Grunts	15,000	1,150	100	6	512	26	113,679	3,629	129,291	4,811
Hickory shad	158,443	13,388	20,500	2,000	13,007	2,035			191,950	17,423
Hogfish							250	11	250	11
Jewfish							12,487	365	12,487	365
King whiting			40,125	4,707	27,230	1,468	297,008	15,604	364,363	21,779
Ladyfish							1,280	13	1,280	13
Leatherjacket or "turbot"							370	13	370	13
Menhaden	179,910,599	1,306,489			29,484,600	88,453	48,362,600	210,175	257,757,799	1,605,117
Moonfish							7,970	245	7,970	245
Mullet:										
Fresh	812,679	52,734	58,050	4,223	10,650	693	10,417,889	397,147	11,299,268	454,797
Salted	315,350	38,341	142,700	14,906					458,050	53,247
Parrotfish							3,500	70	3,500	70
Perch, white	617,088	31,150							617,088	31,150
Perch, yellow	223,813	10,147							223,813	10,147
Permit							7,290	244	7,290	244
Pigfish:										
Fresh	264,272	12,675					14,762	451	279,034	13,126
Salted	3,125	63							3,125	63

Pike	20,552	1,898							20,552	1,898
Pinfish or sailor's choice	50,179	1,225	2,300	148			442,535	13,033	495,014	14,406
Pompano	8,685	994					133,419	19,889	142,104	20,883
Porgies			2,000	130			5,950	328	7,950	458
Porkfish							1,710	57	1,710	57
Scup					12,000	900			12,000	900
Sea bass	111,650	10,928	132,000	13,200	292,615	23,765	41,331	2,699	577,596	50,592
Sea gar or needlefish							100	5	100	5
Sergeantfish or snook							314,774	8,629	314,774	8,629
Shad	1,657,036	376,696	167,462	29,085	100,540	26,960	963,606	135,844	2,888,644	568,585
Sharks			20,000	175	1,289	30	63,775	526	85,064	731
Sheepshead	26,223	1,839	2,100	210	400	25	104,303	4,115	133,026	6,189
Skates			2,000	15					2,000	15
Snapper:										
Mangrove							23,186	975	23,186	975
Mutton							241,078	7,399	241,078	7,399
Red					112,349	7,810	20,200	2,000	132,549	9,810
Spanish mackerel	149,440	14,270					3,061,965	218,085	3,211,405	232,355
Spot:										
Fresh	1,193,270	52,531	37,000	2,354	1,100	59	393,030	11,998	1,624,400	66,942
Salted	42,825	3,768	25,550	2,085					68,375	5,853
Squeteagues or "sea trout":										
Fresh	3,361,246	209,483	59,150	4,846	39,550	4,097	1,645,223	142,091	5,105,169	360,517
Salted	80	10							80	10
Striped bass	286,528	46,030			125	10			286,653	46,040
Sturgeon	6,916	974	117,225	21,136	39,150	4,700			163,291	26,810
Sturgeon caviar	671	1,497	665	889					1,336	2,386
Suckers	16,464	680							16,464	680
Sunfish	123,980	1,202	3,000	180					126,980	1,382
Tautog	150	9							150	9
Tilefish					35,000	2,400			35,000	2,400
Yellowtail or "silver perch"	31,278	1,379	900	37	2,000	100	43,970	1,279	78,148	2,795
Shrimp	940,120	23,485	55,400	6,220	5,793,465	173,990	8,867,918	266,651	15,656,903	470,346
Crabs, hard	145,605	1,983	18,000	400	8,455	504	52,000	1,800	[1] 224,060	4,687
Crabs, soft	233,705	23,821	300	75					[2] 234,005	23,896
Sea crawfish or spiny lobster							23,503	1,174	23,503	1,174
Clams, hard	197,576	46,598	800	200	120	75	2,400	600	[3] 200,896	47,473
Conch meat							7,000	700	7,000	700
Oysters, market, public	1,500,534	67,380	2,631,755	83,892	481,530	30,884	313,425	15,134	[4] 4,927,244	197,290
Oysters, market, private	18,200	2,900	152,075	12,650	628,292	43,029	145,565	4,994	[5] 944,132	63,573
Scallops	422,832	31,618							[6] 422,832	31,618
Octopus					2,731	268			2,731	268
Terrapin	210	92	1,275	545	2,112	454			3,597	1,091
Turtles	8,400	77			11,250	100	6,850	402	26,500	579
Shark hides	19,125	2,868							19,125	2,868
Other aquatic hides	1,050	157							1,050	157
Total	210,501,750	$2,978,708	3,746,932	$207,690	37,153,953	$416,043	81,211,488	$1,746,175	332,614,123	$5,348,616

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[1] 672,180 in number.

[2] 702,015 in number.

[3] 25,112 bushels.

[4] 703,892 bushels.

[5] 134,876 bushels.

[6] 70,472 bushels.

FISHERIES OF THE GULF STATES, 1918.*

ITEMS	FLORIDA (WEST COAST ONLY)		ALABAMA		MISSISSIPPI		LOUISIANA		TEXAS		TOTAL	
	Number	Value	Number	Value	Number	Value	Number	Value	Number	Value	Number	Value
PERSONS ENGAGED												
On vessels fishing	623		85		601		65		357		1,731	
On vessels transporting	70		33		66		128				297	
In shore fisheries	3,600		365		673		2,093		1,070		7,801	
Shoresmen	868		300		1,527		1,905		459		5,059	
Total	5,161		783		2,867		4,191		1,886		14,888	
INVESTMENT												
Vessels fishing, steam									2	$50,000	2	$50,000
Tonnage									217		217	
Outfit										14,800		14,800
Vessels fishing, gasoline	33	$92,630	11	$31,600	10	$16,900	16	$36,700	30	50,085	100	227,915
Tonnage	360		198		87		137		357		1,139	
Outfit		27,043		9,490		2,640		6,875		17,050		63,098
Vessels fishing, sail	62	309,800	4	15,000	115	184,850	14	16,570	43	85,190	238	611,410
Tonnage	2,069		210		1,469		154		761		4,663	
Outfit		71,520		1,500		33,175		1,200		42,745		150,140
Vessels transporting, gasoline	34	105,800	11	15,200	10	18,500	52	98,440			107	237,940
Tonnage	455		107		124		381				1,067	
Outfit		22,444		2,550		2,195		13,605				40,794
Vessels transporting, sail	50	80,650	5	2,900	25	35,625	6	13,400			86	132,575
Tonnage	1,025		41		410		93				1,569	
Outfit				975		3,055		820				4,850
Boats, sail, row, etc.	2,019	128,900	208	6,865	449	21,985	1,072	39,040	790	68,020	4,538	264,810
Boats, power	1,018	438,962	82	31,325	154	77,520	690	311,100	160	51,300	2,104	910,207
Apparatus, vessel fisheries:												
Seines	1	1,600			79	19,560	14	3,920	33	9,745	127	34,825
Trammel nets			8	600	8	800			3	260	19	1,660
Gill nets	6	120							6	90	12	210
Lines		5,379		530		40		20		1,075		7,044
Otter trawls	16	720	3	120	2	50	1	25			22	915
Dredges					171	5,100	25	750	2	100	198	5,950
Tongs	12	120	3	22	8	48	27	207	93	476	143	873
Sponge apparatus		210										210
Other apparatus		2								1		

Apparatus, shore fisheries:												
Seines	163	61,175	3	600	19	4,710	316	71,955	197	28,125	698	166,565
Trammel nets	146	11,990	138	9,710	89	8,900	62	5,475	62	7,175	497	43,250
Gill nets	1,795	106,070	6	50	....	....	....	....	279	7,725	2,080	113,845
Stop nets	136	6,810	....	....	....	....	....	....	....	....	136	6,810
Lines	....	2,046	....	90	....	363	....	1,102	....	2,889	....	6,490
Otter trawls	107	4,770	43	1,720	101	2,525	149	3,825	....	....	400	12,840
Tongs	284	2,616	224	1,680	365	1,825	1,031	6,459	330	2,053	2,234	14,633
Sponge apparatus	....	70,935	....	....	....	....	....	....	....	....	....	70,935
Other apparatus	....	12,596	....	144	....	1,060	....	1,579	....	1,548	....	16,927
Shore and accessory property	....	619,987	....	178,170	....	786,109	....	671,621	....	413,248	....	2,669,135
Cash capital	....	219,350	....	23,900	....	206,050	....	170,500	....	36,400	....	656,200
Total	....	$2,404,245	....	$334,741	....	$1,433,585	....	$1,475,188	....	$890,100	....	$6,537,859

* From Bureau Fisheries Statistical Bull. 470.

FISHERIES OF THE GULF STATES, 1918.—*Continued*

PRODUCTS	FLORIDA (WEST COAST ONLY)		ALABAMA		MISSISSIPPI		LOUISIANA		TEXAS		TOTAL	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
Amberfish	11,100	$413			900	$45					12,000	$458
Angelfish	20,825	798	6,900	$278			360	$18	124	$7	28,209	1,101
Barracuda	4,860	232									4,860	232
Black drum	57,420	1,735	12,200	593	13,777	507	54,455	1,911	1,873,436	44,394	2,011,288	49,140
Bluefish, fresh	246,168	17,411	8,760	275	2,566	190			3,238	418	260,722	18,294
Bluefish, salted	12,240	915									12,240	915
Blue runner or hardtail, fresh	324,648	6,935	11,000	330							335,648	7,265
Blue runner or hardtail, salted	65,430	2,734									65,430	2,734
Bonito	50,955	2,045									50,955	2,045
Catfish	51,427	3,126	40,663	902	16,108	682	480,420	18,955	262,647	16,407	851,265	40,072
Cero and kingfish	465,860	31,903									465,860	31,903
Cowfish and "shellfish"	300	12									300	12
Crevalle	105,927	3,800									105,927	3,800
Croaker			93,500	3,252	40,600	1,917	383,035	28,862	197,557	9,415	714,692	43,446
Elops or ten-pounder, fresh	267,940	5,402									267,940	5,402
Elops or ten-pounder, salted	9,883	334									9,883	334
Flounders	37,381	2,089	38,607	2,300	37,865	3,030	21,546	1,919	162,361	12,834	297,760	22,172
Groupers	5,626,329	222,215	244,000	10,485	24,656	863	20,000	1,000	20,840	843	5,935,825	235,406
Grunts	87,349	3,618	2,700	59					1,000	100	91,049	3,777
Hogfish	7,344	336									7,344	336
Jewfish	69,844	2,704	2,000	75	8,800	288			39,965	2,514	120,609	5,581
King whiting	35,188	2,126	9,600	312	18,517	966			35,974	3,328	99,279	6,732
Leather jacket or "turbot"	7,756	357									7,756	357
Menhaden, fresh	263,530	6,779			11,050	80			14,118,340	103,080	14,392,920	109,939
Menhaden, salted	21,022	669									21,022	669
Moonfish	650	23									650	23
Mullet, fresh	22,569,736	973,129	1,693,520	67,540	1,229,948	46,801	325,177	15,794	53,275	1,809	25,871,656	1,105,073
Mullet, salted	2,453,930	177,974	6,000	275	209,498	15,632					2,669,428	193,881
Mullet roe, fresh			10	3							10	3
Mullet roe, salted	86,285	17,593			13,985	1,829					100,270	19,422
Permit	7,865	294									7,865	294
Pigfish	6,596	250									6,596	250
Pompano, fresh	235,992	27,262	4,966	799	4,289	688	820	184	14,548	2,007	260,615	30,940
Pompano, salted	3,075	520									3,075	520
Porgies	56,742	2,442			1,400	49					58,142	2,491
Porkfish	2,400	144									2,400	144
Redfish or red drum, fresh	937,490	38,068	23,250	1,127	115,685	8,135	565,899	46,945	1,336,535	80,468	2,978,859	174,743
Redfish or red drum, salted	7,321	366									7,321	366
Sailors choice	21,132	809									21,132	809
Scamp	300	10									300	10
Sea bass	31,644	2,180	600	30	4,380	360	15,100	1,216	6,625	350	58,349	4,136
Sea gar, fresh									80,887	4,697	80,887	4,697
Sea gar, dried							6,500	455			6,500	455

Sergeantfish or snook	73,745	2,568									73,745	2,568
Sharks			600	17	400	12	2,000	60			3,000	89
Sheepshead	988,662	32,627	28,050	1,465	67,612	4,482	276,528	22,044	197,662	12,642	1,558,514	73,260
Snapper, mangrove	103,999	4,359									103,999	4,359
Snapper, mutton	14,100	564									14,100	564
Snapper, red	7,230,168	455,640	798,400	49,075	98,232	6,877	60,000	4,000	1,243,002	93,720	9,429,802	609,312
Spanish mackerel, fresh	3,408,701	244,026	4,284	277	11,531	966	1,775	226	41,354	4,197	3,467,645	249,692
Spanish mackerel, salted	27,200	1,505									27,200	1,505
Spot	37,977	1,519	41,700	1,423	19,090	774	66,625	3,330			165,392	7,046
Squeteagues or "sea trout," fresh	1,630,686	145,534	138,630	6,611	356,070	28,874	1,190,357	110,474	1,613,370	119,328	4,929,113	410,821
Squeteagues or "sea trout," salted	31,625	3,772									31,625	3,772
Sturgeon	4,915	620	2,938	125							7,853	745
Sturgeon caviar and roe	12	12	60	45							72	57
Tang	600	30									600	30
Tarpon	1,800	180									1,800	180
Yellowtail	31,735	1,537					2,200	110			33,935	1,647
Shrimp, green	3,250,468	81,408	1,265,612	38,828	9,147,445	319,595	12,571,861	442,480	164,067	8,791	26,399,453	891,102
Shrimp, dried							743,546	207,325			743,546	207,325
Sea crawfish	322,015	16,064									322,015	16,064
Squid							560	56			560	56
Crabs, hard			95,850	3,292	216,025	5,607	281,925	9,908	193,244	10,672	[1] 787,044	29,479
Crabs, soft					9,000	2,275			700	175	[2] 9,700	2,450
Crabs, stone	24,500	2,600									24,500	2,600
Terrapin	2,475	206	2,938	1,104	5,600	3,900	23,406	7,578	2,850	990	37,269	13,778
Turtles	65,370	4,429			337	20	4,360	218	6,671	447	76,738	5,114
Clams, hard	160,872	14,336									[3] 160,872	14,336
Oysters, market, public	2,602,446	121,049	651,126	22,690	7,503,209	259,414	919,254	33,903	3,292,457	140,046	[4] 14,968,492	577,102
Oysters, market, private	13,496	771	190,575	15,485	1,403,514	47,912	6,936,167	460,396	52,031	3,564	[5] 8,595,783	528,128
Oysters, seed, public			190,190	1,495							[6] 190,190	1,495
Conch	2,000	100									2,000	100
Sponges:												
Glove	2,022	245									2,022	245
Grass	73,033	12,125									73,033	12,125
Sheepswool	276,168	675,781									276,168	675,781
Wire	9,324	2,817									9,324	2,817
Yellow	91,641	34,187									91,641	34,187
Total	54,753,639	$3,420,363	5,609,219	$230,567	20,592,089	$762,770	24,953,876	$1,419,367	25,014,760	$677,243	130,923,583	$6,510,310

[1] 2,361,132 in number.
[2] 29,100 in number.
[3] 20,109 bushels
[4] 2,138,356 bushels.
[5] 1,227,969 bushels.
[6] 27,170 bushels.

FISHERIES OF THE PACIFIC COAST STATES, 1915

PRODUCTS	WASHINGTON		OREGON		CALIFORNIA		TOTAL	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
Albacore or tuna, fresh					[1] 21,024,190	$315,622	21,024,190	$315,622
Albacore or tuna, salted					25,000	481	25,000	481
Anchovies, fresh					81,385	1,730	81,385	1,730
Anchovies, salted					16,000	1,600	16,000	1,600
Barracuda, fresh					3,262,646	111,690	3,262,646	111,690
Barracuda, salted					330,000	13,180	330,000	13,180
Bonito					448,256	12,622	448,256	12,622
Carp	200,000	$4,000	50,000	$750	350,815	6,366	600,815	11,116
Catfish					517,054	24,299	517,054	24,299
Cod, fresh	22,025	421	14,400	288			36,425	709
Cod, salted	5,498,284	180,934			4,952,692	161,695	10,450,976	342,629
Croaker					3,150	65	3,150	65
Flounders, fresh	23,255	586	1,965	40	6,914,063	209,291	6,939,283	209,917
Flounders, salted					9,500	475	9,500	475
Grayfish	7,093,996	15,959					7,093,996	15,959
Hake, fresh					221,252	1,937	221,252	1,937
Hake, salted					24,000	960	24,000	960
Halibut	40,590,705	2,041,279	235,169	9,430			40,825,874	2,050,709
Hardheads					73,423	3,622	73,423	3,622
Herring, fresh	2,129,149	9,655	12,500	383	764,384	7,116	2,906,033	17,154
Herring, salted					50,000	1,000	50,000	1,000
Jewfish, fresh					116,461	1,859	116,461	1,859
Jewfish, salted					138,000	5,020	138,000	5,020
Kingfish					656,003	17,362	656,003	17,362
"Lingcod," fresh	837,110	2,812	12,870	354	570,860	14,687	1,420,840	17,853
"Lingcod," salted					3,500	175	3,500	175
Mackerel, fresh					253,899	6,668	253,899	6,668
Mackerel, salted					6,450	259	6,450	259
Mullet					3,000	300	3,000	300
Perch	14,750	493	11,930	360	216,785	6,057	243,465	6,910
Pike, Sacramento					15,884	449	15,884	449
Pompano					19,350	2,032	19,350	2,032
Rock bass, fresh					895,284	24,110	895,284	24,110
Rock bass, salted					2,750	97	2,750	97
Rockfish, fresh	99,651	2,915	12,000	445	4,336,254	145,816	4,447,905	149,176
Rockfish, salted					8,000	400	8,000	400
Sablefish	575,810	13,782	15,520	388	64,503	1,359	655,833	15,529
Salmon:								
Blueback	5,043,374	345,710	337,027	16,848			5,380,401	362,558
Chinook, fresh	18,188,160	699,771	23,497,052	1,225,393	6,640,933	324,082	48,326,145	2,249,246
Chinook, salted					20,000	2,400	20,000	2,400
Chum	17,156,224	282,517	1,981,879	11,081	[2] 38,093	190	19,176,196	293,788
Humpback	29,998,291	367,521					29,998,291	367,521
Silver	18,630,302	543,241	4,844,844	94,140	240,351	8,962	23,715,497	646,343

Sardines, fresh					4,387,706	27,651	4,387,706	27,651
Sardines, salted					1,400	80	1,400	80
Sculpin					8,813	345	8,813	345
Sea bass			2,000	60	1,221,262	49,381	1,223,262	49,441
Sea trout					6,083	213	6,083	213
Shad, fresh	96,298	1,164	488,625	4,945	6,846,008	66,982	7,430,931	73,091
Shad, salted					10,000	125	10,000	125
Shad roe					27,033	2,491	27,033	2,491
Sharks	399,000	889			67,972	236	466,972	1,125
Skates	229,000	515			177,650	868	406,650	1,383
Smelts	2,158,371	25,333	3,500	175	1,137,072	52,978	3,298,943	78,486
Sole	32,062	951			5,761,929	108,254	5,793,991	109,205
Spanish mackerel					396,905	11,555	396,905	11,555
Splittail					17,016	384	17,016	384
Steelhead trout	2,114,141	91,389	2,365,858	75,332	32,405	1,288	4,512,404	168,009
Sting-ray					605,000	1,512	605,000	1,512
Striped bass					1,784,448	146,928	1,784,448	146,928
Sturgeon	43,656	2,151	97,785	5,014	16,924	987	158,365	8,152
Sturgeon roe					1,275	708	1,275	708
Sturgeon caviar	300	75					300	75
Surffish					127,500	7,255	127,500	7,255
Tomcod			22,500	900	41,912	939	64,412	1,839
Whitebait					56,250	2,250	56,250	2,250
Yellowtail, fresh					1,094,416	26,123	1,094,416	26,123
Yellowtail, salted					124,500	4,743	124,500	4,743
Miscellaneous fishes					17,232	539	17,232	539
Abalone, alive					24,026	517	24,026	517
Abalone meat					730,974	16,830	730,974	16,830
Abalone shells					74,000	1,890	74,000	1,890
Abalone pearls and blisters						1,240		1,240
Clams, hard	175,744	12,191			[3] 65,856	17,583	241,600	29,774
Clams, soft	1,200	150	22,460	3,041	67,160	18,107	90,820	21,298
Clams, razor	372,750	56,446	77,200	10,900			449,950	67,346
Mussels	700	83			19,240	2,326	19,940	2,409
Oysters, eastern, market	265,013	140,028			375,774	165,573	640,787	305,601
Oysters, native, market	450,394	250,298	1,547	725	8,435	6,513	460,376	257,536
Oysters, native, seed	24,808	[4] 8,619					24,808	8,619
Octopus					32,309	2,717	32,309	2,717
Squid	15,000	325			6,211,325	32,626	6,226,325	32,951
Crabs	1,734,410	54,526	415,272	13,755	1,414,155	128,434	3,563,837	196,715
Crawfish			183,720	20,747	550	265	184,270	21,012
Spiny lobsters					892,392	130,119	892,392	130,119
Shrimp	386,420	18,719			298,000	5,550	684,420	24,269
Turtles					206	13	206	13
Whale oil	2,635,125	112,851					2,635,125	112,851
Whalebone	6,000	4,200					6,000	4,200
Other whale products	1,292,000	24,390					1,292,000	24,390
Sea lion					9,375	4,120	9,375	4,120
Kelp	450,000	191			5,000,000	2,500	5,450,000	2,691
Other seaweeds					6,799	325	6,799	325
Total	158,983,478	$5,317,080	34,707,623	$1,495,494	92,513,457	$2,488,098	286,204,558	$9,300,672

[1] Includes 5,131 pounds of yellowfin, valued at $145.

[2] Taken in Columbia River by California fishermen.

[3] Includes 640 pounds of cockles, valued at $164.

[4] Value estimated.

FISHERIES OF THE PACIFIC COAST STATES, 1915.*—*Continued*

ITEMS	WASHINGTON		OREGON		CALIFORNIA		TOTAL	
	Number	Value	Number	Value	Number	Value	Number	Value
Persons engaged	14,609		5,870		8,457		28,936	
Vessels fishing	472	$2,194,660	6	$22,650	73	$354,375	551	$2,571,685
Tonnage	11,363		74		3,198		14,635	
Outfit		578,825		3,285		52,791		634,901
Vessels transporting	140	689,248	30	84,184	18	66,500	188	839,932
Tonnage	2,213		267		184		2,664	
Outfit		63,895		11,850		5,510		86,255
Scows (5 tons and over)	297	142,660			2	5,500	299	148,160
Tonnage	7,258				146		7,404	
Boats, power	1,565	644,755	1,382	582,485	1,430	1,353,110	4,377	2,580,350
Boats, sail, row, etc	2,631	98,015	1,264	69,805	1,187	105,216	5,082	273,036
Seines	574	280,020	75	35,125	154	28,035	803	343,180
Gill nets	2,883	309,309	3,877	582,740	4,103	417,846	10,863	1,309,895
Pound nets	444	1,100,103	39	22,700			483	1,122,803
Trammel nets					2,320	59,400	2,320	59,400
Paranzella nets					44	9,000	44	9,000
Lampara nets					65	29,500	65	29,500
Hoop nets	2,487	7,497	680	995	4,860	13,585	8,027	22,077
Dip nets	67	134			11	64	78	198
Reef nets	8	425					8	425
Fyke nets					2,485	21,640	2,485	21,640
Bag nets					70	2,000	70	2,000
Lines		68,000		2,443		12,407		82,850
Beam trawls	21	1,815			9	400	30	2,215
Wheels	2	1,000	27	107,800			29	108,800
Pots and traps	4,945	8,477	5,768	4,828	4,307	9,437	15,020	22,742
Dredges, tongs, rakes, etc		4,811		539		1,620		6,970
Abalone outfit						2,460		2,460
Whaling apparatus		2,050						2,050
Shore and accessory property		7 386,709		2,083,913		2,731,390		12,202,012
Cash capital		546,500		448,809		545,327		1,540,636
Total		$14,133,908		$4,064,151		$5,827,113		$24,025,172

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* From Bureau Fisheries Statistical Bull. 386.

2. CANNED FISHERY PRODUCTS OF THE UNITED STATES AND ALASKA, 1922 * †

CANNED SALMON.

PRODUCTS	PACIFIC COAST STATES								ALASKA								GRAND TOTAL	
	WASHINGTON		OREGON		CALIFORNIA		TOTAL		SOUTHEAST		CENTRAL		WESTERN		TOTAL			
	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value
Cobo or silver:																		
½-pound flat	48,551	$470,494	25,706	$215,445	......	......	74,257	$685,939	20,013	$151,666	2,224	$17,039	......	......	22,237	$168,705	96,494	$854,644
1-pound flat	49,244	337,320	27,618	194,877	......	......	76,862	532,197	10,773	63,515	1,291	8,005	35	$166	12,009	71,686	88,961	603,883
1-pound tall	45,704	271,854	7,439	43,183	......	......	53,143	315,037	91,861	462,365	36,919	192,234	12,877	67,800	141,657	722,399	194,800	1,037,436
Total	143,499	$1,079,668	60,763	$453,505	......	......	204,262	$1,533,173	122,647	$677,546	40,434	$217,278	12,912	$67,966	175,993	$962,790	380,255	$2,495,963
Chum or keta:																		
½-pound flat	4,627	27,293	636	3,816	......	......	5,263	31,109	3,698	21,228	......	......	......	......	3,698	21,228	8,961	52,337
1-pound flat	76	532	......	......	......	......	76	532	6,185	25,693	......	......	......	......	6,185	25,693	6,261	26,225
1-pound tall	78,387	317,745	3,857	15,917	......	......	82,244	333,662	414,383	1,640,135	91,239	362,440	50,413	202,044	556,035	2,204,619	638,279	2,538,281
Total	83,090	$345,570	4,493	$19,733	......	......	87,583	$365,303	424,266	$1,687,056	91,239	$362,440	50,413	$202,044	565,918	$2,251,540	653,501	$2,616,843
Humpback or pink:																		
½-pound flat	1,506	9,779	......	......	......	......	1,506	9,779	30,725	197,953	12,011	75,745	......	......	42,736	273,698	44,242	283,477
1-pound flat	......	......	......	......	......	......	......	......	28,148	134,268	2,731	13,655	......	......	30,879	147,923	30,879	147,923
1-pound tall	2,045	8,767	......	......	......	......	2,045	8,767	1,273,679	5,461,536	298,226	1,251,399	12,903	54,938	1,584,808	6,767,873	1,586,853	6,776,640
Total	3,551	$18,546	......	......	......	......	3,551	$18,546	1,332,552	$5,793,757	312,968	$1,340,799	12,903	$54,938	1,658,423	$7,189,494	1,661,974	$7,208,040
King, chinook or spring:																		
½-pound flat	69,086	$1,097,429	105,475	$1,772,959	7,669	$138,042	182,230	$3,008,430	2,695	30,640	1,022	$13,341	53	742	3,770	44,723	186,090	$3,053,153
½-pound oval	300	7,440	76	1,885	......	......	376	9,325	......	......	......	......	......	......	......	......	376	9,325
1-pound flat	36,036	446,488	51,356	652,707	4,162	58,268	91,554	1,157,463	1,735	15,209	2,067	20,538	165	2,002	3,967	37,749	95,521	1,195,212
1-pound oval	2,998	56,961	19,552	207,679	......	......	22,550	264,640	......	......	......	......	......	......	......	......	22,550	264,640
1-pound tall	11,304	87,701	6,112	45,048	......	......	17,416	132,749	1,703	11,448	7,076	53,168	14,144	100,585	22,923	165,201	40,339	297,950
Total	119,724	$1,696,019	182,571	$2,680,278	11,831	$196,310	314,126	$4,572,607	6,133	$57,297	10,165	$87,047	14,362	$103,329	30,660	$247,673	344,786	$4,820,280

* From Bureau Fisheries Statistical Bull. 570.

† The statistics for canned clams are given in Table 70.

CANNED SALMON—*Continued.*

PRODUCTS	PACIFIC COAST STATES								ALASKA								GRAND TOTAL	
	WASHINGTON		OREGON		CALIFORNIA		TOTAL		SOUTHEAST		CENTRAL		WESTERN		TOTAL			
	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value
Red or sockeye:																		
½-pound flat........	70,625	1,332,887	12,972	231,755	......	....	83,597	1,564,642	57,783	779,582	89,603	1,257,544	24,510	384,901	171,896	2,422,027	255,493	3,986,669
1-pound flat........	13,440	238,236	....	....	......	....	13,440	238,236	17,579	171,509	59,799	614,403	44,071	437,530	121,449	1,223,442	134,889	1,461,678
1-pound tall........	575	9,550	315	4,473	......	....	890	14,023	57,783	530,278	383,935	3,447,679	1,335,595	11,512,270	1,777,313	15,490,227	1,778,203	15,504,250
Total..........	84,640	$1,580,673	13,287	$236,228	......	....	97,927	$1,816,901	133,145	$1,481,369	533,337	$5,319,626	1,404,176	$12,334,701	2,070,658	$19,135,696	2,168,585	$20,952,597
Steelhead:																		
½-pound flat........	5,525	79,701	11,944	162,457	......	....	17,469	242,158	....	....	......	....	....	....	....	....	17,469	242,158
1-pound flat........	1,551	21,714	6,675	61,783	......	....	8,226	83,497	....	....	......	....	....	....	....	....	8,226	83,497
1-pound tall........	87	1,183	15	156	......	....	102	1,339	....	....	......	....	....	....	....	....	102	1,339
Total..........	7,163	$102,598	18,634	$224,396	......	....	25,797	$326,994	....	....	.... ..	.. ..	....	....	....	....	25,797	$326,994
GRAND TOTAL..	441,667	$4,823,074	279,748	$3,614,140	11,831	$196,310	733,246	$8,633,524	2,018,743	$9,697,025	988,143	$7,327,190	1,494,766	$12,762,978	4,501,652	$29,787,193	5,234,898	$38,420,717

NOTE.—The pack of salmon has been reduced to the equivalent of 48 pounds of fish to the case. The pack of preserved salmon eggs amounted, in Washington, to 72,976 pounds, valued at $55,168, and in Oregon to 33,130 pounds, valued at $16,080, not shown in the above table.

CANNED SARDINES, SHAD, AND ALEWIVES.

Sardines (Herring)[1]	Maine		Sardines (Pilchard)	California		Shad	Washington, Oregon, and California		Alewives	Maryland, Virginia, and North Carolina	
	Cases	Value		Cases	Value		Cases	Value		Cases	Value
In oil:			½-pound oval (48 cans)	7,239	$32,182	½-pound flat (48 cans)	779	$1,620	No. 2 (24 cans)	1,043	$1,994
Quarters (100 cans)	1,454,146	$4,645,436	1-pound oval (48 cans):			½-pound oval (48 cans)	174	3,480	Roe:		
In mustard:			In tomato sauce	601,111	2,518,843	1-pound tall (48 cans)	1,304	4,861	No. ½ (48 cans)	768	4,608
Quarters (100 cans)	101,290	378,163	In mustard	53,993	295,111	Roe:			No. 1 (48 cans)	942	4,134
Three-quarters (48 cans)	213,276	689,008	All others	42,539	264,806	½-pound flat (48 cans)	283	6,045	No. 2 (24 cans)	36,588	128,772
In tomato sauce:			1-pound tall (48 cans)	78	232	1-pound oval (48 cans)	150	2,472			
Quarters (100 cans)	7,166	37,502	¼-pound square (100 cans)	21,124	217,953						
			½-pound square (100 cans)	2,895	32,353						
Total	1,775,878	$5,750,109	Total	728,979	$3,361,480	Total	2,690	$18,478	Total	39,341	$139,508

[1] The quantity of herring utilized was 96,458,400 pounds, valued at $623,198.

Note.—In addition to the pack of fish shown in the tables, there were packed in Maine, Massachusetts, New York, New Jersey, Maryland, Virginia, North Carolina, and Washington, 224,304 cases of miscellaneous fishery products, valued at $840,329.

CANNED ALBACORE, TUNA, BONITO, AND YELLOWTAIL IN CALIFORNIA.

PRODUCTS	One-fourth Pound Round (48 to case)		One-fourth Pound Round (100 to case)		One-half Pound Round (48 to case)		One-half Pound Round (50 to case)		One-pound Round (48 to case)		One-pound Tall (48 to case)		One-pound Oval (48 to case)		Four-pound Tall (12 to case)		Total	
	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value
Albacore	24,962	$126,139	14,820	$222,300	188,235	$1,368,883	9,436	$108,514	34,475	$466,399	....	....	....	....	635	$12,700	272,563	$2,304,935
Tuna, bluefin and yellowfin	37,537	154,757	2,390	24,083	101,764	613,344	....	....	22,926	255,437	....	....	....	....	....	....	164,617	1,047,621
Tuna, striped	34,772	126,678	3,162	33,690	122,310	622,565	....	....	17,502	159,423	....	....	....	....	....	....	177,746	942,356
Bonito	....	....	5,223	34,879	5,368	24,021	....	....	....	....	....	....	....	....	....	....	10,591	58,900
Yellowtail	....	....	....	....	4,088	17,104	....	....	....	....	315	$1,890	....	....	....	....	4,403	18,994
Miscellaneous[1]	22,557	115,785	1,467	14,670	4,049	25,194	....	....	219	1,861	3,051	22,883	205	$1,640	....	....	31,548	182,033

[1] Includes fish flakes, abalone, mackerel, squid, and "tonno."

CANNED SHRIMP AND CRABS.

SHRIMP	GEORGIA AND NORTH CAROLINA		FLORIDA		ALABAMA		MISSISSIPPI		LOUISIANA		TOTAL	
	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value
No. 1 (4 dozen)..........	71,004	$360,161	93,094	$512,054	56,434	$290,676	166,198	$840,319	158,672	$840,306	545,402	$2,843,516
No. 1½ (2 dozen)..........	6,289	33,078	1,724	9,310	3,704	19,333	8,268	42,070	20,492	110,996	40,477	214,787
No. 2½ and No. 10 (2 dozen and ½ dozen)..........	....	....	....	....	812	5,784	....	....	....	....	812	5,784
Total..........	77,293	$393,239	94,818	$521,364	60,950	$315,793	174,466	$882,389	179,164	$951,302	586,691	$3,064,087

CRABS	VIRGINIA, WASHINGTON, MAINE, AND ALASKA	
	Cases	Value
7½-ounce, 8-ounce, and 9-ounce (4 dozen)........	8,401	$95,364
15-ounce and 16-ounce (2 dozen)........	710	8,807
Total..........	9,111	$104,171

CANNED OYSTERS.

SIZES	MARYLAND		NORTH CAROLINA		SOUTH CAROLINA		GEORGIA		FLORIDA		ALABAMA		LOUISIANA AND MISSISSIPPI		TOTAL	
	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value	Cases	Value
4-ounce cans (4 dozen)..........	9,710	$47,023	3,756	$16,526	7,601	$28,797	....	....	....	....	568	$2,386	46,381	$199,250	68,016	$293,982
5-ounce cans (4 dozen)..........	39,312	203,099	18,881	78,924	84,710	369,240	17,639	$78,308	14,019	$66,357	27,168	117,607	117,650	534,544	319,379	1,448,079
6-ounce cans (4 dozen)..........	11,320	119,747	....	....	96	768	500	4,000	....	....	....	....	....	....	11,916	124,515
8-ounce cans (2 dozen)..........	2,414	11,927	2,500	9,500	3,425	12,127	....	....	....	....	816	3,229	19,112	82,320	28,267	119,103
10-ounce cans (2 dozen)..........	16,657	85,352	3,863	16,117	24,065	100,933	648	2,863	15	68	10,745	48,485	37,494	171,495	93,487	425,313
12-ounce cans (2 dozen)..........	1,459	12,424	....	....	....	....	25	200	....	....	....	....	....	....	1,484	12,624
Total..........	80,872	$479,572	29,000	$121,067	119,897	$511,865	18,812	$85,371	14,034	$66,425	39,297	$171,707	220,637	$987,609	522,549	$2,423,616

APPENDIX II

List of Common Names and Descriptions of Marine Fish and Animals of Commercial Importance of the United States and Alaska.† *

Abalone (*Haliotis*).—A mollusk found on the coast of California, especially abundant in the neighborhood of San Diego. It is also called "sea-ear," "ormer-shell," "ear-shell," etc. Different species are known as red abalone, black abalone, and rough abalone. The shells are largely sold for commercial purposes, many being shipped to Europe. The flesh is salted and dried and used for food. In recent years, some abalones have been canned.

Albacore (*Germo alalunga*).—This species is pelagic, inhabiting the tropical seas; it is rarely seen on the Atlantic Coast, occurring on the Pacific Coast from San Francisco southward. Its flesh is rather coarse and is used largely for canning. Its maximum weight is about 65 pounds. Also see Horse Mackerel.

Alewife (*Pomolobus pseudoharengus and P. æstivalis*).—These two species are generally known indiscriminately as alewives, and are found in waters adjacent to the sea. *P. pseudoharengus* is never found south of the Neuse River, in North Carolina. It is known along the Potomac as "branch herring"; on the Albemarle as the "big-eyed herring" and the "wall-eyed herring"; in New England as "alewife," and on the Connecticut as "ellwife" and "ellwhop." It appears in the rivers three or four weeks earlier than the "glut herring" or the shad. *P. æstivalis* is found from Florida to the Gulf of Maine. It is known in the Chesapeake and Albemarle as "glut herring"; in the Ogeechee as "English herring"; in the St. Johns as "herring," and in Massachusetts and during the later runs in the Rappahannock as the "blueback"; also known as "black-belly," "saw-belly," and "kyack." It is much less abundant than *P. pseudoharengus,* and much less valuable as a food fish. Both species average about a half pound in weight and from 8 to 10 inches in length. They are caught in nets, seines, weirs, etc., and are of very great importance as a food fish. They are also used for bait. The name, alewife, is also applied to the menhaden (*Brevoortia tyrannus*) in Delaware, Maryland, and Virginia.

Alfione (*Rhacochilus toxotes*).—A food fish found on the California coast from Cape Mendocino to San Pedro. It is also called "perch" and "sprat." It reaches a length of 18 inches and a weight of 5 pounds. It is the most important of all of the surf-fishes.

Alligator (*Alligator mississippiensis*).—The alligator is found in the streams and swamps of the southern states, and more or less numerously along the coast from South Carolina to Texas. It is also called "cayman." Alligators attain a length of 12 feet, and average about 10 feet. They are captured for their hides, oil, ivory, flesh, skeletons, and eggs.

Amber-fish.—Also known as "amber-jack," "jack-fish," "shark's pilot," and "rudder fish." At least three Atlantic species are included, viz.: *Seriola zonata, S. lalandi,* and *S. dumerili.* They range to the West Indies. *S. dumerili* is an important food fish at Key West, where it reaches a length of about 4½ feet, and a weight of at least 75 pounds.

Anchovy (*Engraulididæ*).—These are small fishes of the genus *Anchovia* common on the Atlantic Coast from Cape Cod to Texas; also on the coast of southern California, and the genus *Engraulis* common from Alaska to Lower California. The silver anchovy (*Anchovia browni*) is the common Atlantic species. It is also known as "sardine" and "spearing," and with other anchovies enters into the composition of "white bait." The California anchovy (*Engraulis mordax*) is the largest and most valuable food species. It is mostly preserved in oil or made into fish paste. The name is also applied to preparations of other fish, especially young herring and sprat.

Angel-fish.—1. A name applied to the spadefish or "porgee." *Chætodipterus faber.* Range Massachusetts to Brazil. On the Atlantic Coast of Panama and elsewhere it is an important food fish. 2. Small beautifully tinted fish (*Holacanthus*) found in tropical waters especially along coral reefs. They are sold for exhibition in aquaria and also for food.

Atka-fish (*Pleurogrammus monopterygius*).—A fine food fish found among the Aleutian Islands. The average weight is about 2 pounds and average length about 16 inches. Also known as "Atka mackerel."

Barracuda (*Barracuda argentea*).—An excellent food fish caught on the California coast from San Francisco southward. It reaches a length of about 5 feet and a weight of about 12 pounds. It is caught with hand lines and by trolling, and when dried and salted makes excellent food. The great barracuda (*B. barracuda*), also known as "picuda" or "becuna," is found on our coast from Pensacola to Charleston and is the largest of the genus, reaching a length of 6 feet. Smaller species (*B. borealis* and *B. guachaucho*) are found as far north as Cape Cod, but are not highly valued as food fish.

Bass.—See Redfish, Rock bass, Sea bass and Striped bass.

Beluga (*Delphinapterus leucas*).—A whale abundant in the north Atlantic, north Pacific, and Arctic Oceans. Specimens are occasionally taken as far south as Cape Cod. It is also called "white whale," "whitefish," "porpoise," "dauphin blanc," "marsoon," etc. It attains a length of 15 feet and is captured for its oil and skin. The oil from the jaws is sold under the name of "porpoise-jaw oil"; the skin is made into leather.

Big-eyed mackerel.—See Chub mackerel.

Bill-fish.—A name applied to the gar-pike (*Lepisosteus osseus*), to the garfish (*Tylosurus marinus*), and to the spearfish (*Tetrapturus imperator*).

Blackfish (*Globicephalus melas*).—An important and abundant small whale found on the Atlantic Coast as far south as New Jersey. It is also called "pilot whale," "grind whale," etc. Its average length is from 15 to 18 feet; average weight, 1,000 pounds. It is captured by being stranded on the shore and by harpooning, and is valuable for its oil. Fishermen sometimes use this whale for food and bait. The name is also applied to the sea bass (*Centropristes striatus*) south of Cape Hatteras and about Martha's Vineyard, and to the tautog (*Tautoga onitis*) on the coast of New York and New Jersey.

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† From *Fisheries of the United States, 1908,* Bureau of Census (1911), Appendix C.
* Corrected and appended by Samuel F. Hildebrand, ichthyologist, Bureau of Fisheries.

Blenny (*Blenniidæ*).—Small fishes of little economic value, found on the Atlantic, Pacific, and Gulf coasts, sometimes sold in the market as "eels."

Blinks. — One-year-old mackerel, graded fourth in the markets.

Blister.—A very young oyster.

Bloater.—A fat herring or mackerel light salted and light smoked.

Blueback.—1. An important salmon (*Oncorhynchus nerka*) found on the Pacific Coast from the Columbia River northward. In the upper Columbia and in Alaska it is called "redfish"; in the lower Columbia, "blueback"; in Puget Sound, "sockeye"; and in the Fraser River, "suk-kegh." It averages about 8 pounds in weight and ranks next to the Chinook salmon in value at the canneries. 2. The name is also applied to the "glut herring" (*Pomolobus æstivalis*) in Massachusetts and in the later runs of the Rappahannock.

Blue cod.—See Cultus cod.

Bluefish (*Pomatomus saltatrix*).—A very gamy food fish found on the Atlantic and Gulf coasts. On the coast of the New England and Middle states it is called "bluefish"; in Rhode Island, "horse-mackerel"; south of Cape Hatteras, "skipjack"; in North Carolina, Virginia, and Maryland, "tailor" and "greenfish"; in the Gulf of Mexico, "bluefish." Young bluefish are called "snapping mackerel," "snappers," and "salt-water tailors" in some parts of New England; "blue snappers" about New Bedford, and "skip mackerel" about New York. Bluefish vary in weight from 1 to 20 pounds, according to season and locality. Large numbers are caught during the summer months with nets, traps, seines, and hand lines. The name is improperly applied to the squeteague (*Cynoscion regalis*) from southern New Jersey to Virginia, to the black sea-bass (*Centropristes striatus*) at Newport and New Bedford, to the "greenfish" (*Girella nigricans*) on the California coast south of Monterey, and to the bonito (*Sarda sarda*) in the markets.

Bluefish mummichog.—See Mullet.

Blunt-nosed shiner (*Selene vomer*).—A familiar food fish found along the Atlantic Coast from Florida to Cape Cod and in the Gulf of Mexico. It is known in various places as "hogfish"; in North Carolina, as "moonfish" or "sunfish"; in Florida, as "moonfish"; at Woods Hole, as "humpbacked butterfish"; and in the New York market and Narragansett Bay, as "pug-nosed shiner." It is from 8 to 12 inches long.

Boccaccio.—See Rockfish.

Bonito (*Sarda sarda*).—A food fish found on both coasts. It weighs from 2 to 10 pounds, and is caught with hand lines and in nets. The name is also applied to all the larger scombroids, and to the cobia (*Rachycentron canadus*) in the Chesapeake.

Bowhead (*Balaena mysticetus*).—A whale of great commercial importance found in the Arctic regions. It is the most valuable of all whales. It yields large quantities of oil. It has the finest and longest baleen.

Butterfish (*Poronotus triacanthus*).—A food fish found on the Atlantic coast from Maine to Florida. It is called "butterfish" in Massachusetts and New York, "harvest-fish" in New Jersey, "dollar fish" in Maine, "sheepshead" and "skipjack" about Cape Cod, "pumpkinseed" in Connecticut. It has an average length of 7 to 8 inches, and is caught in traps, seines and pounds.

Cabrilla.—A name applied indiscriminately to several serranoid fishes of the southern coast of California. They are also called "rock bass," "kelp salmon," "Johnny Verde," "lockee cod" (Chinese), etc. They are from 1 to 2 feet long, weigh 2 to 5 pounds, and are used extensively for food.

Candlefish.—See Eulachon. The black candlefish (*Anoplopoma fimbria*) is found on the Pacific Coast from Monterey northward.

Caplin (*Mallotus villosus*).—A small fish of the smelt family found in the north Atlantic as far south as Maine, in Bering Sea, and in the Arctic Ocean. It reaches a length of about 12 inches. It is valuable food for other fish, especially the cod, and is used extensively for bait. They are caught in seines and dip nets, generally at night. The name is incorrectly applied to the silverside (*Menidia notata*) in the vicinity of Boston.

Catfish (*Siluridæ*).—The American species include the sea catfishes of the Atlantic Coast, the channel cats of all the rivers east of the Rocky Mountains, the horned pout widely distributed through the brooks and ponds of the states, and the diminutive mad toms. The various species are distinguished by the common names of "channel cat," "blue cat," "Mississippi cat," "mud cat," "flannel-mouth," "horned pout," "bull-head," "minister," "goujon," "bashaw," "gaff-topsail," etc. The marine catfishes are sparingly used for food in the United States.

Cavalla.—See Crevallé.

Cero.—See Spanish mackerel.

Cetaceans.—Marine mammals, more or less fishlike in form, found in all seas, such as whales, dolphins, porpoises, etc.

Channel-bass.—See Red-drum.

Chicken halibut.—A name applied to small or young halibut. They are sold at a slightly higher price per pound than the common-sized fish. The name is also incorrectly applied to the summer flounder (*Paralichthys dentatus*).

Chinook salmon.—See Quinnat.

Chogset (*Tautogolabrus adspersus*). — This fish is found mostly in bays and harbors on the coast north of New York. It is also called "cunner," "sea perch," "perch," "bergall," "nippers," "bait-stealer," etc. It is similar to the tautog in appearance and is generally associated with it; it is from 8 to 10 inches long, and weighs about 1 pound. It is caught in bag nets and with hook and line and in some localities used for food.

Chub.—This name is given most frequently to various species of the *Cyprinidæ*. They are found in all parts of the United States, but have no great value as food fish. The name is also applied to the tautog (*Tautoga onitis*) in New Jersey and in the Chesapeake, to the spot (*Leiostomus xanthurus*) at Charleston, S. C., and to the large-mouth black bass (*Micropterus salmoides*) in North Carolina.

Chub mackerel (*Stomber japonicus*).—A food fish of much less value than the common mackerel, which it closely resembles. It is found irregularly along the Atlantic and Gulf coasts and in the Pacific as far north as San Francisco. It is also called "thimble-eye," "big-eyed mackerel," "bull mackerel," "easter mackerel," "tinker mackerel," and "little mackerel." It reaches a length of about 1 foot, and on account of its small size very little attention is paid to it where the common mackerel is found.

Cigar-fish.—See Round robin.

Clam.—A name given to bivalve mollusks largely used for food and bait; found on all our coasts. Various species, most of which are edible, are known by the names of "soft clam," "long clam," "butter-fish," "mananose," "manninose," "squirt clam," "quahaug," "hard clam," "surf clam," "sea clam," "hen clam," "beach clam," "dipper," "skimmer," "painted clam," "cuneata clam," "round clam," "little-neck clam," "gapers," "tellens," "flat clam," "razor clam," "razor-fish," "knife-handle," "bullnose," etc. The fishing or digging of these bivalves forms an important industry in the Atlantic, Gulf and Pacific states. Dredges, rakes, tongs, hoes, forks, and baskets are used in gathering them. Large quantities are salted or pickled and sold for bait; they are also canned for food.

Coal-fish (also called skilfish and black cod) (*Anoplopoma fimbria*).—A fish found from Unalaska to Monterey, Cal., valued as food in the northern part of its range. Its usual length is about 18 inches. Also see Cobia.

Cobia (*Rachycentron canadum*).—One of the food fishes of Maryland and Virginia, and found less abundantly along the entire coast from Cape Cod southward. It is called "bonito" and "coalfish" in the Chesapeake; "sergeant-fish" in southern and eastern Florida; "ling" and "snooks" in western Florida; and "crab-eater." It averages from 2 to 3 feet in length.

Cod (*Gadus callarias*).—One of the most important food fishes of the United States. It is caught most extensively along the coasts of the Middle states, New England, and British America. It varies in weight from 3 to 75 pounds. It is caught with hand lines, trawls, nets, etc., and is sold fresh, pickled, salted, and dried. Food preparations, such as boneless and desiccated fish, are also made from cod. The Alaska cod (*Gadus macrocephalus*) is an important food fish found from Bering Sea to Oregon.

The skilfish (*Anoplopoma fimbria*) is known as the "black cod." The redfish (*Sebastodes melanops*) is known as the "red cod."

The cultus cod (*Ophiodon elongatus*) is always called "codfish" where the true cod is unknown.

Conger eel (*Leptocephalus conger*).—Found on the Atlantic Coast from Cape Cod to Brazil, but seldom used as food.

Conch (*Strombus gigas*).—A large sea snail found on the Atlantic Coast and extensively gathered and sold for ornaments, for the manufacture of porcelain and lime, and for medicinal purposes. The animal is used as food in Key West and elsewhere. A valuable pearl is sometimes derived from it.

Crab.—A general term applied to various kinds of decapod crustaceans found along the entire coast. The different species vary much in size, habit, and use, and are designated blue, fiddler, green, hermit, horseshoe, jonah, kelp, king, lady, mud, oyster, red, rock, sand, sea, soldier, spider, stone, etc. The edible crabs have names applied by the catchers, describing the different conditions of the shell. While shedding they are known as "hard-shell," "comer," "buster," "peeler," and "shedder"; while growing a new shell, "soft-shell," "paper-shell," "buckler," and "hard-shell." The gathering of crabs is an important industry along the entire Atlantic Coast. They are caught with scrapes, dip nets, trawls, dredges, hand lines and tongs, and are used for food, bait and fertilizers.

Crab-eater (*Rachycentron canadum*).—This fish, which is also called bonito in the middle Atlantic States, is found from Cape Cod southward. It is a food fish of commercial importance, reaching a length of 2 to 3 feet.

Crevallé (*Caranx hippos*).—A food fish very abundant on the east Florida and Gulf coasts, and occasionally found as far north as Cape Cod. Local names are "crevallé," "horse crevallé," "horse mackerel," etc. The average weight is 2 pounds. The name is also applied to the cero (*Scomberomorus cavalla*), and to *Caranx crysos*.

Croaker (*Micropogon undulatus*).—A food fish found mostly in the South, but sometimes caught as far north as New York. Local names are "crocus" and "ronco." It averages about 10 inches in length. Large quantities are caught in the Gulf with hand lines and seines, and sell at low prices. It is also abundant in the Chesapeake Bay at certain seasons.

The black or Chinese croaker (*Scæna saturna*), caught chiefly near Santa Barbara and Cerros Island, is a food fish of good quality reaching a length of 15 inches.

The so-called white croaker is *Seriphus politus*. (See Queen-fish.)

The yellowfin croaker (*Umbrina roncador*) is found from San Francisco to Cerros Island, and is a food fish of some importance in that locality.

Also a local name for blue surf-fish (*Embiotoca jacksoni*) at San Diego, and for the fresh-water drum (*Aplodinotus grunniens*) in northern Indiana.

Cultch.—The spawn of the oyster; also materials used to form the spawning bed for oysters.

Cultus cod (*Ophiodon elongatus*).—A common food fish found on the Pacific Coast from Sitka to Santa Barbara. Common names are "codfish," "ling," "bastard cod," "buffalo cod," "blue cod," etc. It averages about 8 pounds in weight, and is caught on hooks and in sweep nets.

Cuneata clam (*Gnathodon cuneatus*).—This clam is found in large quantities in the Gulf of Mexico and is used as an article of food. The shell is used for road making. The famous shell roads of parts of the South are constructed of these shells, taken from Lakes Pontchartrain and Salvador.

Cunner.—See Chogset.

Cusk (*Brosme brosme*).—A deep-water food fish found in the Atlantic Ocean north of Cape Cod.

Cuttle-fish (*Cephalopoda*).—Mollusks found in large numbers all along the coast. The "common squid," "octopus," "calamary," "sea arrow," etc., are different species found in particular localities. They are caught in fish pounds, seines, weirs, and trawls, and with fishhooks; large numbers are also taken by driving them on shore by "torching." Some are caught with a peculiar arrangement of hooks called a "squid jig." Different species vary in length from a few inches to 50 feet. They are important as a bait for many useful fish and as food for man. Oil, "cuttle bone," a dentrifice, india ink, etc., are also obtained from them.

Diamond-back.—See Terrapin.

Dogfish (*Squalus acanthias*).—A shark found abundantly in the north Atlantic, sometimes ranging south to Cuba. On the Pacific Coast is found *S. sucklii*. It reaches a length of 3 feet. They are captured for their livers and skins, the former producing large quantities of oil, and the latter, when dried, being used for polishing purposes. The names "smooth-dogfish," "horned dogfish," etc., are applied to related species. The name dogfish is also applied to the bowfin (*Amiatus calva*) in the region of the Great Lakes and to the burbot (*Lota maculosa*) about Lake Erie.

Dolphin.—1. Cetaceans abundant everywhere in temperate and tropical seas; also known by the names of "porpoise," "cowfish," "herring hogs," "puffers," etc. Dolphins are from 5 to 15 feet long and weigh from 100 to 500 pounds. They are captured in nets, by harpooning and by driving them ashore, and are used for bait and for the oil and leather they produce. 2. A pelagic fish (*Coryphæna hippurus*) sometimes found on our coasts from Cape Cod southward. It reaches a length of 6 feet.

Drum (*Pogonias cromis*).—1. A large food fish found plentifully in the south Atlantic Ocean and Gulf of Mexico and occasionally taken as far north as Cape Cod. The young and adult fish are respectively known as "striped drum" and "black drum." The average weight is 20 pounds. They are caught in seines and gill nets and with hook and line. The large and silvery scales are used in the manufacture of "fish scale jewelry." 2. The redfish or red drum (*Sciænops ocellatus*) is a large fish reaching a length of 5 feet and a weight of 75 pounds. See Redfish.

Dun-fish.—Cod or other fish that are slack-salted and dried or cured in a dark room until they turn an amber or dun color. They are much esteemed for food.

Eel (*Anguilla rostrata*).—A very common food fish found in all parts of the United States east of the Rocky Mountains in both fresh and salt waters. Eels are caught in weirs, nets, traps, pots, baskets, and with spears and hand lines, and are sold fresh and canned. The skin is used for mechanical purposes.

Eulachon (*Thaleichthys pacificus*).—A small fish common in the rivers and coast waters of the north Pacific. The Indian name "oolican" (hoolakins) is often used. The trade name is "candlefish." On the Columbia River the name "smelt" is used. The length averages a little less than 1 foot. It is an excellent food fish, and is also of importance for the oil it yields, which is used as a substitute for cod-liver oil.

Finback (*Balænoptera physalus*).—This is a large whale common to all seas. It attains a length of about 70 feet, and is captured by stranding or by the use of the bomb lance. It yields very little oil or baleen. Other species are found in the north Atlantic and on the Pacific Coast.

Flatfish.—A name applied to a large group of fishes which have the body much compressed, both eyes on one side of the head, the blind side colorless and usually lowermost in the water. It is the common name given to the family of flounders (*Pleuronectidæ*).

Flounder (*Pleuronectidæ*).—The family of flounders is composed of turbots (*Bothinæ*), the halibuts (*Hippoglossinæ*), the plaices (*Pleuronectinæ*), and probably the soles (*Soleidæ*). The species caught on the Atlantic Coast commonly called flounders are the summer flounder (*Paralichthys dentatus*), the southern flounder (*P. lethostigmus*) the gulf flounder (*P. albiguttus*), the winter flounder or common flatfish (*Pseudopleuronectes americanus*), the eel-back flounder (*Liopsetta putnami*), and the pole flounder or craig flute (*Glyptocephalus cynoglossus*). Those commonly called flounders on the Pacific Coast are Jordan's flounder (*Eopsetta jordani*), the diamond flounder (*Hypsopsetta guttulata*), the double-lined flounder (*Lepidopsetta bilineata*), the great flounder (*Platichthys stellatus*), the spotted flounder (*Psettichthys melanostictus*), and the long-finned flounder (*Xystereurys liolepis*).

Fur Seal (*Callorhinus ursinus and C. alascanus*).—Fur-bearing sea mammals found from California northward, especially abundant upon the Pribilof and Commander Islands. *Callorhinus alascanus* is the fur seal of the Pribilof Islands. Its fur is of great value. Its flesh is not used as food except by the natives.

Garfish (*Tylosurus marinus*).—A fish of little economic importance common on the Atlantic and Gulf coasts from Maine to Texas. It often ascends rivers for great distances. It is also called "needlefish" in the gulf of Mexico, "garfish" on the Atlantic Coast, and "teasnipe," "silver gar," and "billfish" in different localities. It is about 2½ feet long and weighs about 2 pounds. Other species are known as "needle-fish" and "houndfish" or "agujon."

Garrupa (*Sebastodes atrovirens*).—This species is abundant on the coast of California. It reaches a length of 15 inches.

Gaspereau.—The Canadian name for the alewife (*Pomolobus pseudoharengus*).

Gizzard Shad (*Dorasoma copepianum*).—A food fish of mediocre quality, also called "nanny shad" and "mud shad" which is found in fresh and brackish waters at all seasons and is landlocked in ponds. It occurs not only along the Atlantic Coast but also throughout the Mississippi Valley.

Goldfish (*Carassius auratus*).—A small fresh-water fish, closely allied to the carp, native to eastern China. They are used chiefly as ornaments for aquaria. The name is also applied to a California damsel-fish (*Hypsypops rubicundus*).

Goody.—See Spot.

Goosefish (*Lophius piscatorius*).—A large sluggish fish found on the north Atlantic Coast from Nova Scotia to Cape Hatteras. Local names are "angler," "fishing frog," "monkfish," "bellows-fish," "molligut," "all-mouth," "wide-gape," "kettleman," etc. It reaches a length of 4 feet and a weight of 40 pounds. Although palatable, it is seldom used for food, being principally used as bait for lobster pots.

Grampus (*Grampus griseus*).—A large dolphin taken on the Atlantic Coast. It is also called "cowfish." It attains a length of 15 to 20 feet, and is valuable for the oil it yields. A smaller species (*G. stearnsii*) is found on the California coast.

Gray whale (*Rhachianectes glaucus*).—A large whale found along the Pacific Coast; also called "devilfish," "hard-head," "gray back," "rip sack," "mussel digger," etc. It averages 35 or 40 feet in length, and is captured for its oil and baleen.

Green-fish (*Girella nigricans*).—This fish, which is sometimes called opal-eye, is a food-fish of fair quality found from California to Cape San Lucas. It reaches a length of about 1 foot.

Green turtle (*Chelonia mydas*).—This turtle is found on the coast from Long Island Sound to Florida and along the Gulf coast. In the different localities it varies in size, from 8 pounds at Beaufort, N. C., to 1,000 pounds at Cedar Keys, Fla. The flesh of this turtle forms the basis of the well-known turtle soup; the eggs are valuable for food and for the oil they yield. A closely related species is found on the coast of southern California.

Grilse.—A young Atlantic salmon on its first return to fresh water, usually in its second year of life. It then weighs from 2 to 6 pounds, and is of great value as a food fish. See Salmon.

Grouper (*Epinephelus*).—A food fish found off the south Atlantic Coast and in the Gulf. The different species are known as "red grouper," "brown snapper," "red-bellied snapper," "blackgrouper," "jewfish," "warsaw," "spotted hind," "banded grouper," "rockfish," etc. They vary in size greatly, the "jewfish" exceeding 100 pounds. All are caught with hook and line. The name "grouper" is also applied to the rock cod of southern California and to the triple-tail of the St. Johns River.

Grunt.—The name of several *Hæmulidæ* quite common off the south Atlantic and Gulf coasts, and sometimes found on the California coast. Different species are known as "black grunt," "red-mouth grunt," "flannel mouthed porgy," "pigfish," "hogfish," "sailor's choice," "sargo," "porkfish," etc. All are caught with hook and line and are valued as food fish. They make a peculiar grunting noise when taken out of the water.

Haddock (*Melanogrammus æglefinus*).—A food fish found in the Atlantic north of the Delaware capes; called "dickie" in some localities. It averages in weight from 4 to 6 pounds. It is extensively caught for a fresh food fish, and is also salted, pickled, and dried. When slack-salted and smoked it is sold under the name of "Finnan haddie." Trawls and hand lines are used in their capture.

Hake (*Urophycis*).—Not true hakes. A food fish found off the Atlantic Coast from Newfoundland to Cape Hatteras. Different species are known as "old English hake," "squirrel hake," "white hake," "ling," "king hake," "codling," etc. They are often prepared under the trade name of "boneless fish." They average from 1½ to 2 feet in length and 3 to 8 pounds in weight, and are caught near muddy bottoms with trawls and hand lines and in weirs and traps. They are eaten fresh, and are salted and dried, and pickled in barrels. The sound, or air bladder, is used in the manufacture of isinglass. The name is also applied to the kingfish (*Menticirrhus saxatilis*) on the coast of New Jersey and Delaware. The California hake (*Merluccius productus*) and the New England silver hake or "whiting" (*Merluccius bilinearis*) are true hakes.

Halibut (*Hippoglossus hippoglossus*).—The largest and most valuable of the flat fishes; found in the North Atlantic and Pacific Oceans. It is one of the largest species used for food, sometimes weighing over 625 pounds. The average weight is from 50 to 75 pounds. It is caught with trawls and hand lines. Small young fish, weighing from 10 to 20 pounds, are called "chickens," and are much sought after by epicures. Halibut are sold fresh and are also cured and smoked. The napes are pickled. Other species known as halibut are the arrow-toothed halibut (*Atherestes stomias*) which is caught from the Bering Sea to California, and the bastard or chicken halibut (*Paralichthys californicus*) which is found from Southern California to the Gulf of California and is an important food fish, reaching a length of about 3 feet and a weight of 60 pounds. See also Flounder.

Haliotis.—See Abalone.

Hawk'sbill turtle (*Chelonia imbricata*).—This turtle is found on the Atlantic coast south of North Carolina and throughout the Gulf. It is also called the "tortoise-shell turtle." It reaches a weight of about 300 pounds. It is of no value for food, but is caught for the hornlike scales or plates which cover its bony shell, which form the "tortoise shell" of commerce. A closely related species is found on the Pacific Coast.

Herring (*Clupea harengus*).—A very important food fish found in the north Atlantic as far south as Sandy Hook; it is never found in brackish or fresh waters. "Sperling" and "brit" denote differences in the age of the fish. They weigh from one-half to 1 pound; average length, 10 inches. They are caught in pounds, traps, weirs, and gill nets, and by "torching." As a food fish they are used fresh, salted, pickled, smoked, and canned; used also extensively for bait in the cod, haddock, halibut, and hake fisheries. In Maine, the young are extensively canned and marketed as sardines. The name is also applied to the Gulf menhaden (*Brevoortia patronus*) on the Texas coast and to the menhaden (*B. tyrannus*) in southern Florida. The thread herring (*Opisthonema oglinum*) is a bony fish of little value as food which is found from Massachusetts to Brazil. The "big-eyed herring" (*Elops saurus*) appears in America north to the Carolinas and the Gulf of California. The California herring (*Clupea pallasii*) is found the entire length of the Pacific Coast. The Rocky Mountain whitefish (*Coregonus williamsoni*) is called "mountain herring" in Utah. For "branch herring," "big-eyed herring" "wall-eyed herring" "glut herring," "English herring," "spring herring," and "summer herring," see Alewife; for "fall herring" see Mattowacca. The skip-jack or blue herring (*Pomolobus chrysochloris*) is occasionally taken in salt water; it is bony and not extensively used as food.

Hogfish (*Lachnolaimus maximus*).—A much-esteemed food fish found about the Florida reefs, where it is caught by line fishermen. It averages 3 to 5 pounds in weight. The name is also applied to the log perch (*Percina caprodes*), to the pigfish (*Orthopristis chrysopterus*), and to the blunt-nosed shiner (*Selene vomer*).

Horsefish.—See Blunt-nosed shiner. The name is also applied to the sauger (*Stizostedion canadense*).

Horsefoot.—A local name for the horseshoe crab or king crab.

Horse-mackerel (*Thynnus alalunga*).—The largest of the mackerel family, found on the Atlantic Coast to Newfoundland and on the California coast to Monterey Bay. Also called "tunny," "tuna," and "albacore." The average length is about 8 feet. A good food fish and yields much oil, etc. The name is also applied to the bluefish (*Pomatomus saltatrix*) in Rhode Island; to the jurel (*Caranx chrysos*) at Fort Macon; to the crevallé (*Caranx hippos*); to the California hake (*Merluccius productus*) on the Pacific Coast; to *Trachurus picturatus* and to several other Pacific Coast species of little importance.

Horseshoe crab (*Limulus polyphemus*).—A crustacean found on the Atlantic Coast in large numbers; also called "king crab," "horsefoot," etc. It is caught by hand and in pounds and weirs, and is used for both bait and food, but most extensively for fertilizing purposes.

Humpback (*Megaptera nodosa*).—A whale found in both the Atlantic and Pacific Oceans. It attains a length of 50 feet. It is valuable for its oil, but the baleen is short and of poor quality.

Humpbacked butterfish.—See Blunt-nosed shiner.

Jack.—A name applied to the common pickerel (*Esox reticulatus*) in the South, to the bocaccio (*Sebastodes paucispinis*) on the Pacific Coast, and to the wall-eyed pike (*Stizostedion vitreum*) in the South.

Jack-fish.—See Jurel.

Jewfish (*Stereolepis gigas*).—The largest food fish found on the Pacific Coast, sometimes reaching a weight of 800 pounds. It is also called "black sea-bass." The name is also applied to the black grouper (*Garrupa nigrita*) in Florida and Texas, and to the tarpon (*Tarpon atlanticus*) in Georgia and Florida. *Promicrops guttalus* is also commonly called jewfish or "spotted jewfish" and is found on both coasts of tropical America.

Jurel (*Caranx chrysos*).—A food fish found along the Atlantic and Gulf coasts. It is known about Pensacola as "jurel" and "hard-tail"; along the Florida coast as "jack-fish" and "skipjack"; in South Carolina as the "horse crevallé"; at Beaufort as the "horse-mackerel"; and about New York and on the coast of New Jersey as the "yellow mackerel." They measure from 12 to 18 inches in length, and are caught in seines.

Killer whale (*Orca orca*).—A whale from 15 to 30 feet long that abounds in both the Atlantic and Pacific Oceans, but is seldom captured. The Makah Indians of Washington consider them choice food. The jaws, studded with strong, conical teeth, are sold as curiosities.

King crab.—See Horseshoe crab.

Kingfish (*Menticirrhus saxatilis*).—A food fish found on the coast of the Middle and South Atlantic states, and occasionally on the Gulf Coast. It is called "hake" in New Jersey, "tomcod" in Connecticut, "black mullet" in the Chesapeake, "sea mink" in North Carolina, and "whiting" in the South. Also a common name for the cero (*Scomberomorus cavalla*).

King salmon.—See Quinnat.

Ladyfish (*Albula vulpes*).—A fish of wide distribution in temperate and tropical waters; found on the Atlantic Coast as far north as Cape Cod, in the Gulf of Mexico, and on the Pacific Coast to San Diego. On account of its beautiful color it sells readily, but is not much esteemed as a table fish. In Florida it is known as "bonefish" and is much sought by anglers among the winter tourists.

Lamprey (*Petromyzonidæ*).—A fish of little commercial value, found in nearly all the fresh and brackish waters of the United States. It is also known by the names "lamper eel," "nine-eye," etc.

Lant (*Ammodytes americanus*).—A small fish found on the north Atlantic Coast, probably as far south as Maryland, and *A. personatus* in California and Alaska. It is also known as the "sand eel" and "sand-lance," because it frequently imbeds itself in the sand. The average length is about 10 inches.

Ling.—A local name given to the hake (*Urophycis*) in the Gulf of St. Lawrence and south of Cape Cod; to the burbot (*Lota maculosa*) in Lake Ontario, the lakes of western New York, and in the New York market; to the mutton-fish (*Zoarces anguillaris*) in different localities; to the cobia (*Rachycentrom canadum*) in western Florida; and to the cultus cod (*Ophiodon elongatus*) about Puget Sound.

Lobster (*Homarus americanus*).—A decapod crustacean of great economic importance, found on the Atlantic Coast from Delaware to Labrador. It averages about 11 inches in length and about 2 pounds in weight, but the size varies with localities and seasons. It is caught in pots and traps especially constructed for this fishery. The "spiny lobster" of California and Florida is a different species; it averages 3½ pounds in weight.

Loggerhead (*Thalassochelys caretta*).—A turtle of small economic value, found in the Atlantic as far north as Massachusetts and in the Gulf of Mexico. It reaches a weight of 1,500 pounds, but those taken average only about 50 pounds. They are caught by divers. Only a small number are sold for food, as the flesh is not palatable, but the eggs are highly esteemed. An inferior quality of oil is obtained from this turtle.

Lump-fish (*Cyclopterus lumpus*).—An unwieldy fish, widely distributed throughout the north Atlantic, ranging on the coast as far south as Chesapeake Bay. The average weight is about 5 pounds. It is of little economic value, but on account of its bright colors is often found in the markets.

Mackerel (*Scomber scombrus*).—A very important food fish, found in the north Atlantic south to Cape Lookout. They range from 9 to 18 inches in length and ½ to 3 pounds in weight, and are caught in purse seines, pounds, weirs, gill nets, etc., and with hook and line. They are sold fresh, salted, pickled, and canned, and are sometimes used for bait. Small mackerel are known as "spikes" (5 to 6 inches long), "blinkers" (7 to 8 inches long), and "tinkers" (9 inches long). See Atka mackerel, Spanish mackerel, chub mackerel, horse-mackerel.

Mademoiselle.—See Yellowtail.

Manatee (*Trichechus latirostris*).—A sirenian found on the Florida coast in very small numbers; also called "sea-cow." They are from 6 to 8 feet long, and are caught in rope nets and with spears and javelins. On account of their scarcity they have become very valuable as specimens. They are also converted into food, oil, and leather.

Margate-fish (*Hæmulon album*).—A grunt found in southern Florida; known as "porgy," "market-fish," etc. The largest measure 16 inches in length. They are caught mostly for bait, but in some places they are sold for food.

Market-fish.—See Margate-fish.

Marlin.—See spikefish.

Marshbanker.—See Menhaden.

Mattowacca (*Pomolobus mediocris*).—A food fish found on the Atlantic Coast from Cape Cod to Florida, ascending rivers. It is called "hickory shad" and "hicks," particularly in the South; "tailor shad," "tailor herring," and "fresh-water tailor" in the Potomac; and "forerunner" and "fall herring" in some rivers, in allusion to the time of its run and that of the "white shad." It averages 12 to 15 inches in length and 2 to 3 pounds in weight.

Medialuna (*Medialuna californiensis*).—An excellent food fish found on the California coast south of Point Conception; also called "half-moon." It reaches a weight of 3 or 4 pounds and a length of about a foot.

Menhaden (*Brevoortia tyrannus*).—A fish of the herring family, found along the Atlantic seaboard from Maine to Florida, sometimes as far inland as brackish water extends. It is known by a great number of local names, the most common being "pogy," "hardhead," "hardhead shad," "bony fish," "whitefish," "mossbunker," "bunker," "cheboy," "marshbanker," "alewife," "oldwife," "ellwife," "pilcher," "green-tail," "bug-fish," "bug-shad," "bughead," "fat-back," "shiner," "herring," etc. The average length is 10 to 12 inches; average weight two-thirds of a pound to 1 pound. They are caught in purse seines, haul seines, gill nets, set nets, and weirs. They are of economic importance mainly for the oil, fish meal and scrap which are produced from them; they are also used as bait for mackerel, cod, halibut, haddock, sea-bass, etc. As a food they are sold fresh and salted and canned. Another species (*B. patronus*) is found on the Gulf Coast.

Merluccio (*Merluccius productus*).—A poor food fish found on the Pacific Coast from Santa Barbara northward. It is also called "hake," "horse-mackerel," etc. It averages 5 to 6 pounds in weight.

Moonfish (*Chætodipterus faber*). — A food fish caught on the Atlantic Coast from Woods Hole southward, in the Gulf of Mexico, and on the California coast. In the northern parts of the Gulf of Mexico it is called "spadefish"; from Florida to Charleston "angel-fish"; and at Beaufort, N. C., "porgee" and "pogy." The average length is not more than 8 inches. A local name for the blunt-nosed shiner (*Selene vomer*) in North Carolina and Florida.

Mossbunker.—See Menhaden.

Mullet (*Mugil cephalus and M. curema*).—

Two species of mullet are found on the Atlantic Coast, known as the "striped mullet" and the "white mullet." The former is the larger and has 8 instead of 9 rays in the anal fin and 42 instead of 38 scales between the gill openings and base of the caudal fin. The "striped mullet" is found on the Atlantic Coast from Cape Cod to Brazil and on the coast of southern California, ascending streams; the "white mullet" from Cape Cod southward. Local names are "bluefish mummichog," "jumping mullet," "fat-back," "silver mullet," "big-eyed mullet," "blue-back mullet," "liza," or "josea." *M. cephalus* is the most important of all the food fishes of the South, and greatly surpasses *M. curema* both in numbers and in economic importance. It averages about 1 foot in length and 1 pound in weight, but sometimes reaches a weight of 4 to 5 pounds and a length of 24 inches. It is caught in haul seines, gill nets, cast nets, pound nets, etc., and is sold fresh and salted; the roe is also very valuable food, and is sold fresh, salted, smoked and dried. For "black mullet," see King-fish; for "ground mullet," see Whiting. Many suckers of the genus *Moxostoma* are called "mullet," "white mullet," "sucking mullet," etc.

Mummichog (*Pœciliidæ*).—These fish are found in the brackish waters along the Atlantic, Pacific, and Gulf coasts, near the mouths of rivers, and in many of the fresh-water streams and lakes. Along the eastern coast they are known as "mayfish," "killifish," and "fundalus"; on the Gulf as "sac-à-lait"; and in the interior as "minnows." They are all small fish, rarely exceeding 4 inches in length. They are not commonly used for food, but are of much importance as food for larger fish and for bait.

Mussel (*Mytilus edulis*).—A black, thin-shelled, salt-water mollusk, found on the Atlantic Coast as far south as North Carolina and on the Pacific Coast to Monterey. They are not used extensively for food, but in New York they are pickled and sold to a local trade. The shells are used as a cultch for young oysters, for paint holders, and for ornaments. Large quantities of another genus (*Modiola*) are sold to farmers among the New Jersey and Long Island coasts for fertilizer. The fresh-water mussels (*Unionidæ*) are of much value as food for mammals and birds. The shells are used extensively in making pearl buttons.

Mutton-fish (*Zoarces anguillaris*).—A food fish found on the Atlantic Coast from Delaware to Labrador. It is also called the "eel-pout," "mother-of-eels," "congo eel," "ling," and "lamper eel." It reaches a length of about 20 inches and a weight of 3 pounds. The name is also given to the snapper (*Lutianus analis*), found from Massachusetts to Brazil.

Nanninose.—See Clam.

Narwhal (*Monodon monoceros*).—A dolphin found along the northern coast of Alaska and in the Arctic Ocean; also known as the "unicorn." It is 10 to 14 feet long, and bears a tusk 9 feet long. It is captured for its tusks, oil, and flesh.

Norway Haddock.—See Rosefish.

Octopus.—See Cuttle-fish.

Oldwife.—See Menhaden.

Otter (*Mustelidæ*).—The fresh-water otter (*Lutra canadensis*) is widely distributed over the United States. The sea-otter (*Enhydris marina*), highly prized for its skin, is found in the North Pacific. Both are rare.

Oyster (*Ostrea virginica* or *Ostrea elongata*, Solander).—The most important bivalve found on the coast. There are two classes, "native" and "plants." The former are found on the entire coast; the latter in localities where the cultivation of the oyster is particularly profitable. Oysters are obtained by dredging, raking, and tonging, and are very extensively used in the canning industry. The shells are used in manufacturing lime and cement, for building highways and for chicken food. Native oysters will open about 1 gallon to the bushel; plants do somewhat better. Oysters are graded as "extras," "boxes," "culls," and "cullinteens" according to age, the "cullinteens" being the youngest.

Pearl oyster.—An oyster found on the California coast and in the Gulf of California. The shells are used in manufacturing various useful and beautiful articles.

Periwinkle.—A common name for the sea snail (*Littorina*) and whelk (*Fulga*) which are used for bait and sometimes for food on the north Atlantic Coast. It also constitutes a large portion of the food supply of various fishes.

Pigfish.—A name applied to the genus *Orthopristis* of the family of grunts, found on the southern coast.

Pilot-fish (*Naucrates ductor*).—A pelagic fish of no economic importance, and seldom taken on our coast. It reaches a length of about 2 feet, and is generally found in the company of ships and sharks.

Pinfish (*Lagodon rhomboides*).—A small fish of little commercial importance found from Massachusetts to the West Indies. See Sailor's choice.

Plaice.—A flat fish found on both coasts of America. The winter flounder (*Pseudopleuronectes americanus*) is a common food fish of New England. Other species are known as "rusty-dab," "eel-back flounder," "craig-fluke," "pole-flounder," "flukes" on the Atlantic Coast; as "great starry flounder," "slippery sole," etc. on the Pacific Coast. See Flounder. The true plaice (*Pleuronectes platessa*) is a European species not found in American waters.

Pogy.—A name applied to the menhaden (*Brevoortia tyrannus*) north of Cape Cod, to the moonfish (*Chætodipterus faber*) and the scup (*Stenotomus chrysops*) along the southern coast, and to the surf-fish (*Damalichthys argyrosmus*) on the coast of Oregon.

Pollack (*Pollachius virens*).—A food fish of importance, found mainly off the New England coast. It sometimes occurs as far south as Virginia. The average weight is about 10 pounds. They are caught with seines, nets, and hand lines. For food they are sold fresh, salted, and dried. The skin and heads are used in the manufacture of glue. The Alaska pollack is *Theragra chalcogramma.*

Pompano, or **Pampano** (*Trachinotus carolinus*).—An excellent food fish, found on the Atlantic Coast from Cape Cod to the Gulf, being very common on the Florida coasts. They average 8 to 10 inches in length and 1 to 2 pounds in weight. Other species found on our eastern coast are the "old-wife," or "gaff-topsail pompano"; the "round pompano," or "Indian River permit"; the "permit" or "great pompano," which is frequently not distinguished from the "common pompano" (*T. carolinus*) by the fishermen. The poppyfish (*Palomets simillimus*) is miscalled the "California Pompano." It is a delicate food fish. The round pompano (*T. falcatus*), found from Cape Cod to Brazil, is not of great economic importance in the United States.

Porgee, or **Porgy.**—A name given to the surf-fish (*Damalichthys argyrosomus*) in Oregon and Washington; to the moonfish (*Chætodipterus faber*) at Beaufort, N. C.; to the scup (*Stenotomus chrysops*) in New York and along the southern coast; to the sailor's choice (*Lagodon rhomboides*) in the St. Johns River and at Cedar Keys; and to several sparoids of the Gulf, including *Calamus bajonado* and *C. calamus.*

Pork-fish (*Anisotremus virginicus*).—See Grunt.

Porpoise (*Phocæna communis*).—A cetacean found on the north Atlantic and north Pacific coasts, ascending rivers. It is known as "harbor porpoise," "herring-hog," "puffer," "snuffer," "snuffing pig," etc. It reaches a length of 4 or 5 feet. They are captured in pounds, seines, and mackerel gill nets. They are not used for food, but an oil is obtained from their jaws which is much used for lubrication of watches and other delicate machinery. The skin is tanned and made into leather. The name is also applied rather indiscriminately to many dolphins.

Prawn.—See Shrimp.

Quahaug (*Venus mercenaria*).—An edible clam, found very abundantly from Cape Cod to Florida. It is also called "hard clam," "round clam," "bull-nose," "little neck," etc. They are gathered by raking.

Queen-fish (*Seriphus politus*).—A small food fish of excellent quality found on the Pacific Coast south of Tomales Bay. It is also called "king-fish." The average weight is about half a pound.

Quinnat (*Oncorhynchus tschawytscha*).—The species of the salmon family mostly used for canning. It is found on the Pacific Coast from Monterey northward. It is also called "chinook salmon," "king salmon," "Columbia River salmon," "salmon," etc. The average weight is 16 to 22 pounds.

Racer.—A shad that has spawned and is lean and worthless.

Ray (*Raiæ*).—A general name given to a large group of fishes found on all our coasts. They are also called "skates," "torpedoes," "devil-fishes," etc. They sometimes attain an enormous size, measuring 6 feet across the back and 10 feet in length. They are caught on trawls and in seines, and some are used for food; oil is obtained from the livers of some, and the skin is sometimes manufactured into leather called "shagreen."

Razor clam (*Siliqua patula*).—The most important Pacific Coast clam is found on all sandy beaches from Oregon to Alaska. It is canned in large quantities.

Razor-shell (*Ensis directus*).—A long, slender clam which is a common inhabitant of sand bars and sand flats in New England where the water is pure. It is also called "razor-fish," "razor-clam," "knife-handle," etc. It is sometimes used for food, and its shells are sold for ornaments. The California razor-shell is a different species (*Solen sicarius*).

Red drum.—The redfish (*Sciænops ocellatus*) —Also known as "channel-bass."

Red-eye.—See Rock bass.

Redfish (*Sciænops ocellatus*).—1. A food fish found on the coast from Cape Cod to the Rio Grande. It is commonly known as the "red drum." In Chesapeake Bay and south to Cape Hatteras it is called the "drum"; in the Carolinas, Florida, and the Gulf, "bass," "sea bass," "reef bass," and "channel bass"; in Florida and the Gulf states, "redfish" and "red horse"; and at various places, "spot." It grows to a length of 5 feet or more and a weight of 75 pounds; average weight, 10 pounds. They are taken with spears, gill nets, and bottom lines. The young fish weighing 5 pounds or less are much esteemed as food. The larger fish are scarcely marketable.

2. The redfish of California (*Pimelometopon pulcher*) is found from Point Conception to Cerros Island. It is also called "fat-head" and "sheepshead." It reaches a weight of 12 to 15 pounds, but is not a valuable food fish.

3. The blueback salmon (*Oncorhynchus nerka*) is also called "redfish" in the upper Columbia and in Alaska.

4. The redfish (*Sebastodes melanops*).—A food fish found from southeastern Alaska to California. It is also known as "red cod," "red rockfish," etc. See Rockfish.

Red horse.—1. A name applied to several species of suckers found in the waters of the West and South. They are all poor food fishes.

2. The redfish (*Sciænops ocellatus*) of Florida and the Gulf.

Red snapper (*Lutianus blackfordi*).—A valuable food fish found off the Florida coast and in the Gulf of Mexico. It attains a weight of 40 pounds, but averages only about half as much. It is caught with hand lines, and is sold fresh.

Robin.—A name applied to the sailor's choice (*Lagodon rhomboides*) about Cape Hatteras.

Rock.—See Striped bass.

Rock bass (*Paralabrax clathratus*).—An excellent food fish, otherwise known as sand bass, found from San Francisco to Lower California. It reaches a length of 20 inches and a weight of 5 pounds.

Rock cod.—See Rockfish.

Rockfish (*Scorpænidæ*).—These fish are caught in enormous quantities on the Pacific Coast, especially from Santa Barbara to San Francisco. There are a large number of species, known to the fishermen as "priest fish," "rock cod," and "rockfish," with many qualifying prefixes, as "black," "black-banded," "brown," "grass," "green," "orange," "red," "yellow," "yellow-backed," "yellowtail," etc.; also called "garrupa," "grouper," "scorpene," "sculpin," "scorpion," "tree-fish," "flyfish," "corsair," "Spanish flag," "reina," "black bass," "jack," "tomcod," "boccaccio," etc. They average 15 inches in length and 2 or 3 pounds in weight, but some reach a length of 3 feet and a weight of 12 pounds. They are caught in seines and with hook and line. The name is also applied to the striped bass (*Roccus lineatus*) along the Atlantic Coast; to the grouper (*Epinephelus*) about Key West and in the Gulf of Mexico.

Rock trout (*Hexagrammidæ*).—A group of fishes of considerable importance on the Pacific Coast. They are the true greenlings. The different species are known as "sea trout," "starling," "boregata," "bodieron," "red rock trout," etc. The size varies greatly, the average being 18 inches long and 2½ pounds in weight.

Roncador (*Roncador stearnsi*).—A food fish of excellent quality, found from Santa Barbara southward; also called "croaker." It reaches a length of over 2 feet and a weight of 6 to 8 pounds. Related species are known as "red roncador," "little roncador," "yellow-finned roncador," etc.

Rosefish (*Sebastes marinus*).—A brilliantly colored fish found off the north Atlantic Coast as far south as New York. It is also called "red perch," "redfish," "Norway haddock," "snapper," "hemdurgan," "bream," etc. The average length is about 12 inches; average weight, 1½ pounds. It is caught on trawl lines.

Round robin (*Decapterus punctatus*).—A food fish found along the coast from the Gulf to Woods Hole. It is also called "cigar-fish" and "scad." It reaches a length of 12 inches.

Rudder-fish (*Kyphosus sectatrix*).—A small fish, also called chub, abundant about Key West; it sometimes reaches a length of 18 inches. The banded rudder-fish (*Seriola zonata*) is found from Cape Cod to Florida, but is of little economic importance.

Runner (*Elagatis bipinnulatus*).—A food fish abundant on the western and southern coasts of Florida. It is also called "skipjack," "yellow tail," and shoemaker." It reaches a length of 2½ feet.

Sailor's choice (*Lagodon rhomboides*).—A food fish found on the Atlantic Coast south of Cape Hatteras and in the Gulf. It is also called "robin," "pinfish," "salt-water bream," "squirrel-fish," "porgy," "scup," "yellowtail," "shiner," "chopa spina," etc. It averages about 10 inches in length and 6 ounces in weight, and is caught with hook and line and in cast nets and seines. The name is also applied to the pigfish (*Orthopristis chrysopterus*) in South Carolina, and to the grunt (*Hæmulan parra*) at Key West.

Salmon (*Salmo salar*).—This is the salmon of the Atlantic Coast. It is found along the coast of the New England states. At different ages the fish are known as "parrs," "smolts," "grilse," "kelts," and "salmon." The adults weigh from 15 to 40 pounds. They are caught with nets, seines, and hand lines, and by spearing. The landlocked salmon, or fresh-water salmon, or Sebago salmon (*S. sebago*), is found in fresh waters, generally landlocked.

The blueback salmon (*Oncorhynchus nerka*) is found on the Pacific Coast from the Columbia River northward. The California salmon, or chinook salmon, or quinnat (*O. tschawytscha*), is found from Monterey to Alaska. The dog salmon (*O. keta*) ranges from the Sacramento River to Bering Strait. The humpbacked salmon, or lost salmon (*O. gorbuscha*), ranges from the Sacramento River to Alaska. The river salmon, or silver salmon (*O. kisutch*), is found in all rivers from the Sacramento River to Bering Strait.

The steelhead or salmon trout (*Salmo gairdneri*) is found from California to British Columbia. It is a good food fish reaching a weight of about 20 pounds.

The California yellowtail (*Seriola dorsalis*) is also known as the "white salmon" on the Pacific coast, as is also the chub (*Ptychocheilus lucius*) of the Colorado River. The name "kelp salmon" is applied to the cabrilla (*Paralabrax clathratus*) at Monterey; "lake salmon," to the lake trout (*Cristivomer namaycush*) in the lakes of northern New York; and "jack salmon" to the "wall-eyed pike" (*Stizostedion vitreum*) in the streams of the south.

Sand-dab (*Hippoglossoides platessoides*).—A rather common food fish of the family of flounders which lives in rather deep water in the north Atlantic on the American coast south to Massachusetts.

Sardine.—The California sardine (*Sardinia cærulea*) is found from Puget Sound to Magdalena Bay. The name is also applied to various other small fishes of the herring family, and is also given to canned herring prepared after the manner of French sardines.

Scallop (*Pecten gibbus*).—An edible bivalve found off the coasts of Long Island, Rhode Island, and southern Massachusetts in paying quantities; less numerous South. It is obtained by dredging and raking. The powerful central muscle by which the animal opens and closes its shell forms the edible portion. The shells are of commercial value. The rims or refuse are used for fertilizers.

The giant scallop (*Placopecten grandis*) is found in deeper water than the common or bay scallop, consequently it is taken only in dredges and trawls. The chief beds are on the coast of Maine and off Long Island and New Jersey.

Scorpions (*Scorpæna guttata*).—A good food fish reaching a length of 1 foot, found from Monterey Bay to Ascension Island. It is sometimes called sculpin.

Sculpin (*Cottidæ*).—Several species of sculpin are found on the Atlantic and Pacific coasts and in inland waters, but none are of particular value as food fish. Those on the Atlantic are called "grubby," "puffing-grubby," "daddy sculpin," "bull-head," "sea-robin," "sea toad," "pigfish," "sea-raven," etc.: those on the Pacific, "drummer," "salpa," "johnny," "biggy-head," "cabezon," etc.: and those in the lakes and streams of the Northern states, "bull-heads," "miller's thumb," "goblins," "blobs," "muffle-jaws," etc. Most of the species are of small size, although some species reach a weight of 25 pounds.

Scup (*Stenotomus chrysops*).—This fish is found along the Atlantic Coast from Cape Cod to South Carolina; abundant North. Common local names are "scuppaug," "paugy," "porgy," "pogy," "fair maid," etc. They are caught in pounds and traps and with hook and line.

Sea bass (*Centropristis striatus*).—A food fish found from Vineyard Sound to the eastern part of the Gulf of Mexico. It is known south of Cape Hatteras as the "blackfish"; in the Middle States as "black Will," "black Harry," and "hannahills"; about New Bedford and Newport as "bluefish"; and at New Bedford also as "rock bass." The average length in New England is about 15 inches; average weight, 1½ pounds. In the South they are much smaller, averaging about three-fourths of a pound in weight. They are caught with hand lines and in pounds and traps. The white sea bass (*Cynoscion nobilis*) is found on the Pacific Coast from Cape Mendocino to San Diego. It is an important food fish, and averages 15 pounds in weight. The redfish (*Sciænops ocellata*) is called "sea bass" in the Carolinas, Florida, and the Gulf.

Sea elephant (*Mirounga angustirostris*).—A marine mammal, 12 to 14 feet long, found on the Pacific Coast. The oil is of commercial value, and the tongues are sometimes salted and used for food.

Sea herring.—The common herring (*Clupea harengus*) of the north Atlantic.

Sea-horse (*Hippocampus hudsonius* and *H. ingens*).—A curious fish found on the eastern coast south of Cape Cod and on the Pacific Coast. Few specimens are taken, and they are sold for curiosities.

Seal (*Pinnipedia*).—The seal tribe embraces the walrus, eared seals, and earless seals. They are found in the northern part of the Atlantic and Pacific Oceans and in the Arctic Ocean. They are captured for their oil, skins, and flesh. The fur-seal fishery is the most important. See Fur seal.

Sea lion (*Eumetopias jubata*).—A seal found on the Pacific Coast from the Farallone Islands to the Pribilof Islands. The males are about 15 feet long, and weigh about 1,000 pounds; the females are about half as large as the males. They are killed with guns and lances, and are used by the natives for food, oil, leather, etc. The California sea lion (*Zalophus californianus*) is found on the California coast from San Diego to San Francisco.

Sea-robin (*Prionotus carolinus, P. evolans, P. scitulus, P. tribulus*, etc.)—These fishes are found along the eastern coast south of Cape Cod. They are also called "gurnards," "wing-fish," "sea bat," etc. They attain a length of 15 to 18 inches and a weight of about a pound. The name is also applied to the toadfish (*Opsanus tau*) in the Gulf.

Sea snails (*Gasteropoda*).—An asymmetrical mollusk bearing a single shell. They are found on all our coasts, and are known as "periwinkles," "whelks," "wilks," "winkles," "wrinkles," "conchs," "drills," "borers," "helmet-shells," "abalones," "ormer-shells," "sea-ears," "limpets," "wood-lice," "lobster tails," "sea-bugs," etc. They are not extensively used for food in this country, but are used for bait in numerous fisheries.

Sea trout.—A name given to the white seabass (*Cynoscion nobilis*) on the Pacific Coast; to the white trout (*Cynoscion nothus*) along the southern coast; to the spotted rock trout or greenling (*Hexagrammos decagrammus*) south of San Francisco; and to the squeteague (*Cynoscion regalis*) on the Atlantic Coast. It is also a trade name for sea herring.

Seekonks.—Oysters (mainly seed) growing in the Seekonk River, Rhode Island.

Sergeant-fish.—See Cobia.

Shad (*Alosa sapidissima*).—A very important food fish found on all the coasts and in some inland waters; the great fisheries are in the rivers of the Atlantic slope. It is called "white shad," in distinction from other "shad." The average weight is about 4 pounds; average length about 1½ feet. It is caught in nets, seines, and weirs, and is sold fresh, cured, and pickled.

The names "mud shad," "gizzard shad," "winter shad," "stink shad," and "white-eyed shad" apply to a different species (*Dorosoma cepedianum*). The hickory shad is *Pomolobus mediocris*. The menhaden is called "hard head shad" about Cape Ann, "bug-shad" in Virginia, and "yellow-tail shad" from North Carolina to Florida.

Sharks (*Notidani*).—Numerous species of sharks are found on the Atlantic and the Pacific coasts . They are variously called "dog-fish," "angel-fish," "porbeagle," "swingle-tail," "bonnet-head," "hammer-head," etc. They are captured with hook and line, gill nets, and with harpoons; sometimes they are taken in nets set for other fish. Sharks are valuable for their livers, from which oil is extracted; their bodies are used mainly for fertilizing purposes; their skins are tanned and make excellent leather.

Sheepshead (*Archosargus probatocephalus*).—A choice food fish caught off the eastern coast of the United States from Cape Cod to Texas. The weight varies from 2 to 12 pounds, according to locality; the average size is about 4 pounds. The southern sheepshead (*A. unimaculatus*) is found from Florida to Brazil but is of much less importance than *A. probatocephalus*. The name is also applied to the butterfish (*Poronotus triacanthus*) about Cape Cod, to the fresh-water drum (*Aplodinotus grunniens*) in the Great Lakes, and to the redfish (*Pimelometopon pulcher*) south of Point Conception, California.

Sheepswool.—The highest grade of Florida commercial sponges.

Shiner.—A common name applied to the redfin (*Notropis cornutus*) from New England to Kansas and Alabama; to the menhaden (*Brevoortia tyrannus*) in southern Florida; to some of the surf-fishes (*Embiotocidæ*) on the Pacific Coast; and to the sailor's choice (*Lagodon rhomboides*) about Cedar Keys. The blunt-nosed shiner is so called about New York and Narragansett Bay. The golden shiner (*Notemigonus chysoleucus*) is found in the rivers east of the Great Plains.

Shrimp.—A decapod crustacean found in large numbers on all our coasts and in many inland waters. The usual length is about 4 inches, but some attain a larger size. They are caught in seines and trawls and other nets. Prawns are generally larger than shrimps, often attaining a length of 7 inches.

Silverfish.—See Tarpon.

Silver Hake (*Merluccius bilinearis*).—This fish is found on the Atlantic Coast north of Virginia. It is also called the "New England whiting." Its average length is 1 foot. It is caught in weirs, nets, and with hand lines, and is used for food and bait.

Silversides (*Atherinidæ*).—A small food fish found along the Atlantic Coast from Cape Hatteras and southward, and from California southward on the Pacific Coast. Different species are known as "sand smelt," "green smelt," "anchovy," "merit-fish," "sardine," "California smelt," "little smelt," "brit," etc. They range from 7 to 18 inches in length and are caught in seines.

Sirenians.—Large marine mammals, more or less fishlike in form, such as manatees, seacows, etc.; found in warm seas.

Skate.—See Ray.

Skilfish (*Anoplopoma fimbria*).—A common food fish from Unalaska to Monterey. It is also known as "beshow," "coalfish," and "black cod."

Skipjack.—A local name applied to the skipper (*Scombresox saurus*) along the Atlantic and Gulf coasts; to the inland alewife (*Pomolobus chrysochloris*) in the Mississippi Valley from the Great Lakes to the Gulf; to the bluefish (*Pomatomus saltatrix*) south of Cape Hatteras; to the bonito (*Sarda chilensis*) on the Pacific Coast; to the runner (*Elagatis bipinnulatus*) about Key West; to the butterfish (*Poronotus triacanthus*) about Cape Cod; to the cutlassfish (*Trichiurus lepturus*); to the jurel (*Caranx chrysos*) along the east Florida coast; and to the leather jacket (*Oligoplites saurus*) on the Atlantic Coast.

Skipmackerel.—A name applied to the bluefish about New York.

Smelt (*Osmerus mordax*).—A very choice food fish found on the Atlantic Coast from Virginia to the St. Lawrence and landlocked in many New England lakes. Also called "American smelt" and "frostfish." When sent to market unfrozen they are known as "green" smelts. The average length is 8 to 10 inches. The Pacific smelt (*O. thaleichthys*) is found from San Francisco to Alaska. The surf smelt (*Mesopus pretiosus*) is found from Monterey to Alaska.

Osmerus dentex, the rainbow ·herring, is a smelt with firmer flesh than the other species found on the Pacific Coast.

The eulachon or candlefish (*Thaleichthys pacificus*) is an excellent food fish found from the Columbia River to Skagway, where it is called "smelt." Some of the silversides (*Atherinidæ*) are wrongly called "smelts"; this is especially true of *Atherinopsis californiensis*, which is widely known as "smelt," "blue smelt," and "California smelt."

Smolt.—A name applied to an immature salmon when it has become a uniform bright silvery color.

Snappers (*Lutianidæ*).—The red snapper (*Lutianus blackfordi*) is the most important of these fishes. It is a large fish, bright red in color, and is found from Long Island southward, but is most abundant on the coasts of Georgia, Florida, and the Gulf states. The gray snapper or mangrove snapper (*L. griseus*), also known in Florida as "lawyer," is a most common species. The mutton snapper (*L. analis*), the dog snapper, or jocu (*L. jocu*), the schoolmaster, or caji (*L. apodus*), the silk snapper (*L. vivanus*), the lane snapper (*L. synagris*), are all fishes of food value common in the West Indies and southern Florida.

The red grouper (*Epinephelus morio*) is called "brown snapper" and "red-bellied snapper" in Florida; the rosefish (*Sebastes marinus*) is called "snapper" on the North Atlantic coast; the bluefish (*Pomatomus saltatrix*) is called "snapper" and "blue snapper" on the New England coast; and the cod that live near the shore away from the ledges are called "black snappers."

Sole (*Soleidæ*).—The American sole, or hogchoker (*Achirus fasciatus*) is common from Boston to Galveston. The rex sole (*Glyptocephalus zachirus*) is found from California to the Bering Sea. It is a rather thin, dry flounder inhabiting deep water. The slippery or Chinese sole (*Microstomus pacificus*) is found from Puget Sound to southern California. The common or California sole (*Parophys vetulus*) is a small but abundant sole found from Alaska to California. See Flounder.

Snook (*Centropomus undecimalis*).—A good food fish, also called the robalo, found from Florida to Brazil. Its greatest length is about 3 feet.

Spadefish.—See Moonfish.

Spanish mackerel (*Scomberomorus maculatus*).—A very choice food fish found on the Atlantic Coast south of Cape Cod and in the eastern part of the Gulf of Mexico. The average length is about 16 inches; average weight about 2 pounds. In California the Monterey Spanish mackerel (*S. concolor*) is a most excellent food fish. They are caught on troll lines and in gill nets and pound nets.

The cavalla (*S. cavalla*) is a West Indian species, but often taken in small numbers on the southern New England coast. It is also known as "kingfish." The name "cero" is often applied to the Spanish mackerel.

Sperm whale (*Physeter macrocephalus*).—One of the most valuable of the whales; found in both the Atlantic and Pacific Oceans. It is also called "cachelot." The males reach a length of 70 feet, the females much less. They are captured for their oil and spermaceti. An intestinal substance called "ambergris" is also very valuable.

Spikefish (*Istiophorus nigricans*).—A large fish, otherwise known as sailfish, sought by anglers, but of slight economic importance. It reaches a length of 8 feet and a weight of 95 pounds. It is found in the warmer parts of the Atlantic north to Florida on the American coast. The marlin (*Tetrapterus mitsukurii*), found on the coasts of Japan and California, is also called spikefish. It is caught chiefly by anglers. Occasionally it reaches a length of 12 feet.

Sponge.—The sponge of commerce is found off the Florida coast. The grades generally rank sheepswool, yellow, velvet, grass, and glove; but different men in the business grade them differently.

Spot (*Leiostomus xanthurus*).—A food fish found along the coast from Cape Cod to Texas. It is called "goody" in New Jersey, "roach" in the Chesapeake, "chub" at Charleston, S. C., "masooka" on the St. Johns, "chopa blanca" at Pensacola, "Lafayette," etc. It is about 6 inches long, and is taken with hook and line and in gill nets. This name is also applied to the spot-fin croaker (*Roncador stearnsi*) caught off the coast of California.

Sprat.—1. A local New England name for the young alewife. 2. See Alfione.

Squeteague (*Cynoscion regalis*).—An excellent food fish found in abundance along the Atlantic Coast from Cape Cod to Florida. It is known as "drummer" about Cape Cod; "yellowfin" about Buzzards Bay; "weakfish" in New York and New Jersey; "bluefish" in Delaware and Virginia; "gray trout," "sun trout," "shad trout," "sea trout," and "salt-water trout" in the Middle and South Atlantic states; and "squeteague," "squit," "chickwit," etc., in various places. It averages about 2½ pounds in weight, though some individuals attain a weight of 30 pounds. They are caught in seines and gill nets and with hook and line. The sounds are of commercial value. The spotted squeteague (*Cynoscion nebulosus*) is found from New Jersey to Texas, and is somewhat larger than the preceding. The California "bluefish" is *Cynoscion parvipinnis*. The great "white seabass" of California is *Cynoscion nobilis*.

Squid.—See Cuttle-fish.

Starfish.—1. A star-shaped animal consisting of a central disk from which radiate five arms or "fingers"; found all along the coast and known as "five-finger," "sea-star," "star," etc. It is of importance only on account of the great damage it does to oyster beds. 2. (*Peprilus alepidotus*). This fish resembles the butterfish but is a much shorter and deeper fish of more southern distribution. It is a common food fish from the Chesapeake southward.

Striped bass (*Roccus lineatus*).—One of the choicest food fishes found along the Atlantic and Gulf coasts, also introduced on the Pacific Coast; it often ascends rivers for several miles. In the North it is generally called the "striped bass"; in the South "rockfish" and "rock." Large specimens are called "green-head" and "squid-hound" by New Englanders. The average length is about 3 feet; average weight about 20 pounds. They are caught in weirs, traps, gill nets, and seines, and with hook and line. The name is sometimes applied to the white bass (*Roccus chrysops*) of the Great Lakes region.

Sturgeon (*Acipenseridæ*).—Large food fishes found on the Atlantic and Pacific coasts and in many inland waters. The various species are known as "short-nosed (*Acipencer brevirostrum*), common sturgeon (*Acipencer oxyrhynchus*), and white or Oregon sturgeon (*Acipencer transmontanus*), and red or green sturgeon (*Acipencer medirostris*). With the exception of the last-mentioned, these fish reach a length of 5 to 12 feet and a weight of 400 to 600 pounds. The flesh is sold in the fresh, pickled and smoked state; caviar is manufactured from their eggs; in Europe, the sounds are manufactured into isinglass. The red sturgeon has red flesh which is considered inferior to that of the other three; it seldom attains a weight exceeding 150 pounds.

Suk-kegh.—See Blueback.

Sulphur-bottom whale (*Balænoptera musculus*).—The largest known cetacean, reaching a length of 100 feet. It is found in the Pacific Ocean, and is captured only by the use of the bomb lance. It is valuable for its oil and baleen.

Sunfish.—The ocean sunfish (*Mola mola*) is found off the entire coast of the United States; also called "headfish." It reaches a weight of 500 pounds, and yields a large quantity of valuable oil.

Surf-fish (*Embiotocidæ*).—A food fish found in large numbers along the Pacific Coast. The general name "perch" is applied to them everywhere along the coast; they are also called "pogy" and "porgy" on the Oregon coast, "surf-fish" south of Monterey, and "minny," "sparada," "moharra," etc., along their northern range. The largest attain a weight of 4 pounds; the average is about 1 pound. See Alfione.

Surgeon-fish (*Hepatus hepatus*).—This is the Tang common from Carolina to Florida. It is a good food fish. Also known as "lancet-fish," "doctor-fish," etc.

Swell-fish (*Tetraodontidæ*).—The different species are known as "globe-fishes," "puffers," "swell-toad," etc. They are common on the Atlantic Coast.

Swordfish (*Xiphias gladius*).—One of the best food fishes found the entire length of the Atlantic Coast, and rarely off the California coast. The average weight is from 300 to 400 pounds. It is captured with harpoons, and is sold fresh, pickled, and salted. The swords are sold as curiosities.

Tailor.—The "salt-water tailor" is the bluefish (*Pomatomus saltatrix*) of North Carolina, Virginia, and Maryland. The "fresh-water tailor" is the mattowacca (*Pomolobus mediocris*) of the Potomac.

Tarpon (*Tarpon atlanticus*).—An immense herring-like fish found in the western Atlantic and Gulf of Mexico. It is also called "jewfish" in Georgia and Florida; "grand écaille," or "grandy-kye," and "savanilla" in Texas and "silver-fish" at Pensacola. It attains a length of 7 feet and a weight of 350 pounds, and is caught on hooks and in seines. It is seldom used for food, but the scales, which are from 1 to 3 inches in diameter, are sold for ornaments.

Tautog (*Tautoga onitis*).—A food fish found along the east coast from Maine to South Carolina. On the New York coast it is called "blackfish"; in New Jersey, "blackfish," "tautog," and "chub"; on the Virginia coast, "Moll" and "Will George"; at the mouth of the Chesapeake, "salt-water chub"; and in North Carolina, "oyster-fish." The average weight is about 2 pounds; average length, about 15 inches. It is caught on hooks, and in pounds, weirs, and nets.

Ten-pounder (*Elops saurus*).—A game fish found in America north to the Carolinas and Gulf of California. Also known as "big-eyed herring," "bony-fish," "piojo," "John Margigle," etc.

Terrapin.—The salt-water terrapin (*Malaclemmys palustris*) is very highly prized for food. It is found in salt marshes along the coast from Massachusetts to Texas, but those which enter into commerce are principally from Chesapeake Bay and the Carolina coast. They are also called "salt-marsh turtle" and "diamond-back." The average weight is 4 or 5 pounds. They are taken in dredges, seines, and nets.

The fresh-water terrapins are generally distributed south of the forty-first parallel of latitude. The most common used for food are the "red-bellied terrapin" (*Pseudemys rugosa*), the "mobilianer" (*P. mobiliensis*), and the "yellow-bellied terrapin" (*P. scabra*).

Thimble-eye.—See Chub mackerel.

Tilefish (*Latilidæ*).—A food fish found along the Atlantic and Gulf coasts, and on the Pacific Coast south of Monterey. The California species (*Caulolatilus princeps*) is also known as the "white-fish" and "blanquillo." The Atlantic species (*Lopholatilus chamæleonticeps*) is abundant at the edge of the Gulf stream southward from Nantucket. All are caught with hook and line.

Tinker mackerel.—See Chub mackerel.

Tomcod.—The Atlantic tomcod (*Microgadus tomcod*) ranges from New York to Newfoundland, often ascending rivers. It is also known as the "frostfish." The Pacific tomcod (*M. proximus*) is found from Monterey northward. Each species reaches a length of about 1 foot and a weight of about one-half pound. They are taken in great numbers in seines and sweep nets, and with hook and line. The name is also applied to the kingfish (*Menticirrhus saxatilis*) on the Connecticut coast, and to the boccaccio (*Sebastodes paucispinis*) on the California coast.

Tortoise.—See Turtle.

Triple-tail (*Lobotes surinamensis*).—A food fish, found on the Atlantic Coast as far north as Cape Cod, abundant South. It is known in South Carolina as "black perch," and on the St. Johns River as "grouper"; it is also called "flasher." It attains a length of from 2 to 3 feet, and is caught with hook and line. The scales are sold as ornaments.

Trout.—See Squeteague.

Trunkfish (*Ostraciidæ*).—Different species are known as "cuck-old," "cowfish," "horned trunkfish," "spotted trunkfish," etc. They are a tropical fish found in small numbers on the Florida coast. Some species have been found as far north as Massachusetts.

Tunny.—See Horse-mackerel.

Turbot.—See Flounder. The true turbot (*Bothinæ*) is not found on the American coast.

Turtles.—See Green turtle, Hawk'sbill turtle, Loggerhead, and Terrapin.

Unicorn.—See Narwhal.

Walrus (*Odontobaenus rosmarus* and *O. obesus*).—A marine mammal, found in the north Atlantic and Pacific Oceans. It attains a length of 16 feet and a weight of 2,000 pounds, averaging about one-fourth less. They are captured by means of the rifle, harpoon, and lance, and are valuable for their oil, tusks, hide, and flesh.

White-fish (*Caulolatilus princeps*).—A food fish of some importance found from California to the Galapagos Islands. It reaches a length of about 40 inches.

Whiting (*Menticirrhus saxatilis*).—This fish is otherwise known as the "kingfish," the "sea-mink," and the "sea mullet"; it is abundant from Cape Ann to Pensacola. The sand whiting (*M. americanus*), also known as the "deep-water whiting," is common from the Chesapeake Bay to Texas. The surf-whiting (*M. littoralis*) also called the "silver-whiting," is common from the Carolinas to Texas. The California whiting (*M. undulatus*) is also known as the "sand-sucker." On the coast of Florida, they are variously known as "kingfish," "barb," "bull-head whiting," and "ground mullet." They attain a length of 10 inches and a weight of 1½ pounds. They are caught with hook and line and with seines, and are a food fish of considerable importance. The name is also applied to the harvest-fish (*Peprilus alepidotus*) at Norfolk, Va., and to the silver hake (*Merluccius bilinearis*) on the New England coast.

Window pane (*Lophosetta maculata*).—A fish belonging to the flounder family found from Maine to South Carolina. It is of slight importance as a food fish, rarely weighing over a pound.

Wolf-fish (*Anarhichas lupus*).—A large fish found off the New England coast north of Nantucket Shoals. It is also called "catfish." The average length is about 4 feet; average weight about 25 pounds. It is caught on hooks and in seines, and is sold fresh, salted, and dried and smoked.

Yellowtail (*Bairdiella chrysura*).—An excellent food fish found on the Atlantic Coast from Cape Cod to Texas; it is especially abundant South. It is called "silver perch" on the coast of New Jersey, and "mademoiselle" at Pensacola. It averages 8 inches in length. *Ocyurus chrysurus*, another fish also called yellowtail, is an important food fish along the Florida keys. It reaches a length of about 2 feet. The name is also applied to the menhaden (*Brevoortia aureus*) from North Carolina to Florida; to the runner (*Elagatis bipinnulatus*) at Pensacola; to the sailor's choice (*Lagodon rhomboides*) in the Indian River region; to the amber-fish (*Seriola dorsalis*) on the California coast south of Santa Barbara; and to the green rockfish (*Sebastichthys flavidus*) at Monterey.

AUTHOR INDEX

A

Abderhalden, E., 673
Adler, R., 414
Agricola, G., 28, 29, 46
Albert, R., 86
Alexander, A. B., 261
Allemand-Martin, A., 690
Allen, A. W., 110
Allen, J. A., 667
Allison, 395
Allodi, R., 690
Almy, L. H., 265, 268, 279, 305, 403, 439, 440
Alsberg, C., 620
Anderson, A. G., 264, 281
Andrews, 144
Andrews, R. C., 646
Annett, H. E., 132
Appert, N., 377
Archbutt, L., 418
Ashbrook, F. G., 474
Atwater, W. O., 268, 279, 386, 528, 530, 534, 564, 584, 595, 605, 609, 620
Audebert, P., 464

B

Bailey, H. S., 438
Baker, H. D., 145, 153
Balard, 63, 67
Balch, D. M., 88, 102, 110
Ball, C. O., 403
Ballantyne, 447
Barclay, M., 376
Bartlett, J. M., 474
Bauder, C. S., 132
Bauer, M., 166, 199
Beal, G. L., 175
Beal, W. H., 145
Bean, T. H., 226
Beard, H., 696, 697
Becker, J. E., 277, 449, 453
Beckmann, J., 166
Beckwith, T. D., 326, 695
Beilstein, F. K., 166
Belding, D. L., 530, 534, 538, 541, 547, 609, 624
Belknap, F. D., 145
Bell, V., 190
Benetter, S. J., 305
Bennett, C. B., 620
Bennett, H. G., 503
Benzoni, V., 113
Bethe, A., 162, 166
Bidder, G., 690
Bigelow, W. B., 624
Bigelow, W. D., 403
Biggar, E. B., 110
Birdwood, G. C. M., 184
Bitter, L., 413
Bitting, A. W., 326, 403, 695, 702
Blackmore, H. S., 27
Blount, E., 376
Bogue, R. H., 482-483, 488, 490
Bohart, G. S., 403
Böhm, E., 428
Bolton, K. C., 27
Bomboletti, A., 113
Boomer, J. F., 176
Borodin, N. A., 403, 410
Bottaro, 428
Bottemanne, J. M., 305
Bower, W. T., 647-667
Boyer, L., 414
Brooks, W. K., 530
Browne, W. W., 695
Bruckmiller, F. W., 110
Bruhl, L., 376
Bruna, J., 297
Bryant, A. P., 609, 620
Budé, G., 147
Bull, H., 305, 417, 439, 440, 447, 456
Bumpus, H. C., 583
Burd, J. S., 110
von Buschman, J. O., 46
Buttenberg P., 376, 413, 439, 534, 576

C

Calvert, 428
Calvert, A. F., 46
Cambon, V., 438
Cameron, F. K., 86, 89, 93, 110, 132, 144
Canestrini, G., 199
Cavolini, F., 673
Chapman, A. C., 451
Chatard, T. M., 46
Chick, H., 277
Christie, A. W., 99
Church, A. C., 46
Churchill, E. P., 506, 508, 530, 563, 564, 572
Clark, E. D., 265, 268, 305, 380-389, 403, 440, 620
Clarke, A. H., 491, 647, 648, 667
Clarke, F. W., 23, 24, 26, 27, 585

Clarke, W. F., 438
Claudy, C. H., 646
Clemens, 387
Clement, L., 169
Clifford, W. M., 282
Cligny, A., 464
Clough, R. W., 380-389, 403
Cobb, J. N., 145, 261, 325, 341, 347, 364, 368, 376, 400, 403, 413, 491, 546, 547, 575, 595, 605, 624, 646, 690, 698
Codefroy, J., 690
Coker, R. E., 189, 530, 605
Cole, H. I., 644
Cole, L. H., 46
Collard, A. O., 530
Collins, J. W., 261
Collins, W. D., 438
Colvin, H. M., 120
Cooper, M., 306
Coppock, J. B., 25
Coste, M., 530, 583
Cotte, J., 199, 690
Coward, K. H., 278, 279
Cowie, J. J., 347
Cox, A. J., 33
Cram, A. B., 110
Crandall, W. C., 89
Croockewitt, 673
Crowther, C., 474
Crozier, W., 275
Cullen, J. A., 99
Cyamo, K., 279

D

Daggett, E., 377
Dahl, A. L., 46
Dahl, N., 298
Dahl, W., 414
Dakin, W. J., 166
Dall, W. H., 547
Danilevsky, A., 414
Darbishire, F. W., 132
Darboux, G., 199
Davidson, J., 414, 438
Dean, B., 530
Del Torre, 113
Deny, 440
Devillers, 82
Dewey, F. P., 110
Dickover, E. R., 438
Dill, D. B., 268, 469
Dittmar, W., 24, 26
Ditmars, R. L., 606
Doane, R. W., 547
Don, J. R., 27
Donald, J., 300
Douglas, L. M., 464
Douglas, W., 300
Downing, W. F., Jr., 59, 60
Drew, G. A., 608
Drummond, J. C., 277, 278, 279, 442, 451, 634, 646, 693
Dubois, R., 149, 690
Ducloux, E. H., 24
Duge, F., 376
Dunkerley, H. M., 305
Dunlap, M. P., 396
Dunlop, 447, 454
Duthrie, R. J., 347

E

Ebaugh, W. C., 110
Eckel, E. C., 46
Edholm, C. L., 624
Edington, 695
Edmondson, C. H., 547, 624
Edwards, C. L., 187, 624
Ehrenbaum, E., 306
Eidsvaag, E., 305
Eitner, 452
Ellingwood, F., 448
Elliott, 387
Elliott, H. W., 667
Ellis, C., 438, 702
Elschner, C., 44, 47
Eschle, Dr., 73
Eto, T., 73
Euler-Chelpin, H. K. A. S. von, 94
Evermann, B. W., 226

F

Faber, G. L., 690
Fahrion, W., 434, 438, 439, 440, 447, 454
Falk, K. G., 376
Farlow, 695
Fearon, W. R., 281
Feil, C. J., 166
Fellers, C. R., 127, 128, 133, 380-389, 403
Fendler, G., 639
Ferrin, A. W., 189
Field, E., 279, 305
Field, G. W., 595
Field I., 117, 118, 129, 141, 620, 621, 624
Filippi, 149
Flanders, F. F., 395
Flegel, C., 690
Flower, W. H., 646
Forbes, A. A., 464
Forsberg, 25
Fortuyn, D., 305
Foster, D. L., 281
Fowler, H. W., 226
Frazer, C. M., 403
Fredmon, S., 414
Freeland, E. C., 110
Frye, T. C., 89, 93, 120
Fullarton, J. U., 547
Funk, C., 276
Fürer, F. A., 46

G

Gadow, H. F., 606
Galloway, R., 86
Gardner, H., 429, 438, 439, 440, 697
Gardner, J. S., 306
Giagobini, E., 690
Glaze, H. L., 110
Gloess, P., 133, 145
Gobley, 275
Goldschmidt, S. H., 428
Goldsmith, E., 46
Goode, G. B., 261, 326, 347, 413, 530, 576, 647
Goodrich, F. J., 528
Gourret, P., 690
Graells, M., 690
Grandmougln, E., 576
Grave, C., 530
Gray, F. H., 574
Gray, T., 146
Green, I. H., 305
Greene, A. M., 306
Greene, C. W., 275, 279
Greene, E. H., 491
Greer, R. L., 261, 418, 419, 458, 459, 702
Grenfell, W. T., 664, 667
Grimme, C., 438
Groth, L. A., 491
Grout, J. H., 413
Gruvel, A., 403
Guillon, 583
Günther, A., 220, 226
Gutsell, J. S., 504-531

H

Hall, A., 261, 350, 376
Hammarsten, O., 673
Hamor, W. A., 702
Hanson, H. H., 403
Hanssen, J., 414
Harnack, 673
Hartwell, B. L., 145
Haselhoff, E., 474
Hay, W. P., 576, 601, 606
de Hemptinne, A., 428
Henderson, J. R., 414
Hendrick, J., 73, 133, 145
Hendrickson, N., 391
Henking, H., 376
Henseval, Dr., 438, 439, 440, 454
Herbst, C., 24
Herdman, W. A., 166, 189
Herrick, F. H., 582, 595
Herubel, M., 23
Hesketh, E., 300, 303
Heyd, W., 193
Heyden, G. van der, 428
Higgins, C. A., 106, 108, 110
Hildebrand, J. H., 69
Hildebrand, S. F., 200-226, 727-738
Hindman, E. F., 528
Hjort, J., 23, 133, 277, 305
Hoagland, D. R., 93, 94, 97, 110, 113, 116, 135, 136
v. Hoff, J. H., 69
Hofmann, W., 86
Holdsworth, E. W., 347
Holmes, 275, 276
Holstein, G. H., 428
Holzapfel, K. A., 414
Hooper, 454
Hooper, D., 133
Hornell, J., 189, 530
Hosie, A., 46
Houghton, H. W., 403
Howell, G. C. L., 23
Humbert, 149
Hume, E. M., 277
Hundeshagen, 673
Hunter, A. C., 388, 403, 530
Huwart, J., 438, 439, 454
Hyatt, A., 690

I

Ingersoll, E., 530, 547, 624
Inkersley, A., 624
Isidore, of Charax, 149, 152

J

Jackson, A. M., 99
Jameson, H. L., 149, 166, 189, 278
Jenkins, J. T., 23, 646
Johnson, J. M., 438
Johnston, E. C., 624, 647-667
Johnstone, J., 403
Joly, 27
Jones, D. B., 610
Jones, F. W., 199
Jordan, D. S., 220, 226, 648, 667
Jorgensen, C., 428
Jorgensen, I., 306
Jousset, C., 414
Juan, T. D., 33
Julien, E. P., 414

K

Keats, J., 146
Keil, G., 166
Kelaart, E. F., 149
Kellner, 472, 473
Kellner, O., 113
Kellogg, J. L., 531, 547, 624
Kelly, J. P., 464
Kemp, E., 531
Kendall, W. C., 261
Kensett, T., 377
Kent, W. Sayville, 166, 606
Kerr, R. H., 265
Keutgen, C. H., 438
Kinch, E., 113, 133, 145
Kleeman, A., 474

Klein, Dr., 475
Klie, A., 330
Knisely, 387
Knudsen, H., 491
Kohler, 494
Kolotoff, S., 25
Krause, A. K., 547
Krefting, A., 136
Kreis, H., 265
Küchenmeister, 149
Kühn-Cornieten, 473
Kunz, G. F., 146-161, 166-199
Kylin, H., 145

L

Lahey, W. G., 441
Lamb, M. C., 503
Lamb, W., 414
Landsborough, D., 133
Langdon, S. C., 94
Langworthy, C. F., 279, 387, 403, 534
Laucks, I. F., 110, 441
Lehmann, F., 473
Leroy, Société de G., et Cie., 166
Lewites, S. J., 127
Lewkowitsch, J., 417, 439, 442, 448, 641, 646
Lexow, T., 435
Lieb, L. L., 136
Lindemuth, J., 93, 110, 462, 464, 472
Lindsley, A., 646
Liverseege, 439
Liversidge, A., 27
Locard, A., 531
Loebisch, W., 25
Loomis, H. M., 377-403
Lotsy, J. P., 624
Lovell, M. S., 547
Lucifero, A., 690
Lucks, R., 475
Luhr, O., 306
Lunge, G., 65
Lusskin, A., 435
Lydekker, R., 646

M

MacDonald, R. M. E., 531
Macintire, H. J., 306
Mahin, F. W., 145
Makin, C. J. S., 24
Mann, 454
Marcet, A., 300, 303
Markham, C. R., 166
Marot, R., 414
Marsh, M. C., 226
Martell, L. H., 464
Martin, G., 46
Martin, G. W., 531
Mason, F. H., 39, 69
Mast, S. O., 214
Matill, H. A., 634
Matsui, H., 129
Maze-Launay, 82
Mazza, C. L., 199
McCollum, E. V., 276, 277, 449, 451
McFarland, R., 261
McGuire, G., 376
McIntosh, W. C., 23
Mead, A. D., 547, 583
Meade, R. K., 110
Meehan, W. E., 413
Meek, A., 226
Megasthenes, 152
Meily, J. J., 598
Mellanby, J., 277
Mendel, L. B., 276
Merck, E., 128
Merle, 63, 65
Merrill, G. P., 46
Merrill, 387
Merz, A. R., 93, 110
Middleton, E. S., 396
Millard, C. K., 624
Milner, 275
Mitchell, C. A., 417
Mitchell, J., 72
Mitchell, J. M., 347
Mitchell, P. H., 528, 531
Mitsukuri, K., 133, 547
Miura, M., 277, 448
Möbius, 149
Molinari, E., 46
Monroe, Paris and Company, 166
Moore, 646
Moore, F. W., 145
Moore, H. F., 261, 403, 531, 668-690, 702
Moore, R. B., 86, 110, 132
Morgulis, S., 584
Mori, K., 277
Morton, E. H., 24
Mulliken, F. G., 376
Münster, C. A., 27
Murray, J., 23
Müther, A., 86
Myers, R. G., 576
Mylius, E., 87

N

Nakatogawa, S., 439
Natterer, K., 25
Nearchus, 152
Neikirk, A., 94
Nelson, T. C., 515, 530
Nettlefold, F., 145
Nicholson, F. A., 414, 547
Nightingale, H. W., 547
Noel, L. v., 376
Norton, T. H., 110
Nuttall, G. H. F., 306

O

Obst, M. M., 403
Okada, H., 441
Okinoto, T., 634
Okuda, Y., 73, 279, 491, 576, 634, 693
Orr, A., 548-560
Osborne, T. B., 276, 610, 693
Osgood, W. H., 667
Oshima, K., 113
Ottesen, A. J. A., 299, 300, 306

P

Pachundaki, M. D. E., 691
Pack, J. W., 27
Paget, G. W., 691
Paisseau, J., 166
Palmer, L. A., 39, 69
Parker, E., 93, 462, 464
Passburg, R., 414
Patton, M. A., 531
Paulmier, F. C., 563
Péchiney, A. R., 63, 65
Pellieux, J., 82
Perlzweig, W. A., 306
Petersen, E., 428
Petersen, P. W., 302, 303, 304, 305
Pettersson, A., 326
Pfund, A. H., 169
Phalen, W. C., 42, 46
Philpots, J. R., 531
Pigopitta, 158
Piqué, J. J., 300
Plank, R., 306
Pliny, 147, 148, 152
Plischke, K., 166
Polimanti, O., 279
Polowinsky, W., 414
Posselt, 673
Potolowsky, 428
Prince, E. E., 580, 595
Procter, H. R., 441, 503
Prollius, F., 491
Pufahl, H., 606

Q

Qvale, A., 414

R

Radcliffe, L., 261, 527, 531, 576, 646, 696, 702
Rankin, E. P., 624
Rappleye, H. W., 300
Rassbach, H., 306
Rathbun, R., 576, 691
Ravndal, G. B., 691
Réaumur, M., 149, 161, 166
Reed, M., 112
Reilley, A., 438, 697
Reuter, K., 306
Riban, J., 644
Richards, H. M., 133
Richardson, A. C., 403
Richardson, W. D., 441
Rigg, G. B., 89, 93, 110
Risser, J., 624
Ritchie, J., 595
Riviere, C., 169
Roberts, W. A., 576
Rogers, A., 492-503
Rogers, G., 445
Rondolet, 149
Roscoe, H. E., 87
Rouart, H., 300
Roughley, T. C., 531
Rozov, 275
Russell, E. J., 145
Russell, E. S., 624
Russell, H. E., 194
Rutter, F. R., 339

S

Sadler, W., 403
Saiki, T., 115
Sale, J. W., 529
Salvesen, T. E., 646
Samuel, A. M., 23, 347
Sandberg, G., 428
Savage, W. G., 403
Scammon, C. M., 667
Schenke, V., 473
Schloesing, T., 24, 25
Schlosstein, H., 441
Schmelck, L., 25
Schmidt, C., 24, 25
Schmidt, O., 674
Schmidt, W. L., 624
Schmidt-Nielson, S., 326
Schneider, G., 414
Schoff, W. H., 149
Scholz, P., 414
Schorlemmer, C., 87
Schrodt, 472
Schroeder, W. C., 547, 597
Schuck, W. P., 428, 441
Schultz, A., 491
Scofield, W. L., 431, 464, 472
Scott, G. G., 374-376
Scott, W. L., 145
Scott, W. R., 87
Seale, A., 347, 368, 376, 407, 414, 606
Sestini, F., 113
Seurat, L. G., 691
Shaler, F. R., 22
Shellford, 533
Sherrin, R. A. A., 407
Shipley, P., 449, 453
Shoaff, P. S., 103
Shostrom, O. E., 387, 403
Siebel, J. E., 306
Simmonds, N., 277, 449, 451
Simmonds, P. L., 23, 129, 166, 194, 491
Sipocz, L., 25
Skinner, J. J., 99

Skinner, W. W., 529
Smith, C. S., 306
Smith, G. A., 414
Smith, H. M., 117, 121, 130, 133, 145, 226, 261, 332, 376, 403, 531, 547, 576, 624, 691
Smith, J. R., 23
Smith, J. V. C., 118
Smith, W., 145
Smith, W. A., 133
Snell, M. M., 261
Sonstadt, E., 27
Soubeiran, J. L., 583
Southall, J. B., 376
Southwell, T., 166, 372, 414
Spencer, G. C., 103
Spooner, W. D., 306
Stafford, J., 531
Stahmer, M., 401, 404, 414
Stanford, E. C. C., 73, 77, 78, 79, 87, 102, 133, 134, 136, 137, 145
Starr, J. E., 306
Steiger, G., 24, 585
Stejneger, L., 648, 667
Stenhouse, J., 103, 145
Stephan, P., 199
Stepp, W., 276
Sterkers, M. E., 80, 81
Stevenson, C. H., 145, 148, 306, 376, 405, 408, 441, 531, 576, 595, 646, 667, 702
Stewart, G. R., 100
Stiles, G. W., Jr., 531
Stiles, W., 306
Stocks, H. B., 141
Stone, R. W., 46
Strauss, E., 673
Streeter, E. W., 166
Stuber, 439
Suzuki, U., 279
Swalm, A., 145
Swan, J. G., 110
Swartz, M. D., 115

T

Tahara, 113
Tanner, H. G., 103
Tavernier, J. B., 190
Taylor, H. F., 262, 279, 280-306, 310, 314, 702
Taylor, W. E., 414
Tern, R., 414
Thomas, A., 441
Thompson, 447
Thompson, L. H., 96
Thompson, W. G., 449
Thompson, W. W., 531
Thomson, 454
Thorpe, T. E., 24
Toch, M., 441
Tollens, B., 86
Tolman, L. M., 441
Tower, W. S., 646
Townsend, C. H., 667
Tracey, H. C., 226
Tressler, D. K., 264, 309, 312, 314, 452, 482, 695, 702
True, F. W., 606
Tsujimoto, M., 417, 435, 441, 451, 452, 454, 645, 664, 698
Turrentine, J. W., 64, 69, 93, 102, 103, 110, 436, 441, 464, 642
Twitchell, E., 429

V

Vaughan, T. W., 199
Vilbuschewitch, M., 441
Villon, A. M., 145
Von Lendenfeld, R., 691

W

Wagoner, F. L., 27
Wallis-Tayler, A. J., 306
Ware, S., 624
Watson, A. F., 448
Watts, H., 87
Weber, F. C., 262, 394, 403, 473
Weidlein, E., 644
Weil, G., 691
Weiske, 472
Weiss, G., 428
Welfling, C. H. J., 428
Wells, W. F., 531
Welsh, W. W., 624
Wheeler, A. S., 24
Wheeler, H. J., 145
White, G. F., 275, 441, 452, 454, 491
White, H. G., 141
Wilcox, W. A., 133, 262, 624
Willcox, G. B., 47, 58
Williams, K. I., 279
Williamson, H. C., 595, 624
Wilson, J. A., 503
Wilson, J. B., 394, 403
Wimmer, 472
Wolfrom, G., 691
Wright, S., 23
Wurtz, 65

Y

Yada, T., 634
Yendo, K., 121
Yoshimura, K., 279
Young, A., 347
Young, E. E., 464
Young, J. D., 414

Z

Zalocostas, 673
Zdarek, 439
Zeller, S. M., 94
Zerban, F. W., 110
Zilva, S. S., 277, 279, 448
Zucker, 277

SUBJECT INDEX

A

Abalones, canning of, 617-618
  description of, 727
  dried, 617
  fishing, 616-617
  habits of, 616
  physiology of, 616
  shells, utilization of, 618
  smoked, 617
  utilization of, 617-618
Abalone fishery, methods, 178
Abalone industry, California, 615-618
  development of, 615-616
Abalone pearls, 156
Abalone shells, 174, 177-178
Abura-garei oil, 439
Acetone, manufacture of, from kelp, 108
Acidulated scrap, 459-460
Adrenaline, 644
Agar, composition of, 127, 128
  manufacture of, Japanese method, 131
  properties of, 127
  purification of, 128
  uses, 129-130
Agar industry, American, 130
  Japanese, 130-132
Air-bladder, of fishes, 212
Akajei oil, 439
Alabama, fishery statistics, 716-719
Alanine, in fish, 272
Alaria fistulosa, botanical characteristics of, 92
  composition of, 93-5
Albacore, canned, statistics, 725
  description of, 727
  fishery, methods, 246
Albacore oil, 439
Alewives, brining of, 334-335
  canned, statistics, 725
  corned, 335
  description of, 727
  distribution of, 223-224
  dry-salting of, 334
  salted, location of industry, 333
  salting of, 333-335
  smoking of, 360
Alfione, description of, 727
Algæ, algin content of, 136
  as animal feed, 97, 140-141
  ash content of, 113
  carbohydrates of, 114
    digestibility of, 115-116
Algæ, characteristics of, 70
  composition of, 73, 74, 75, 81, 83-86, 92-94, 95, 98, 111, 112-114, 122, 129, 136, 139, 140
  economic importance of, 22
  edible, composition, 111-114
    digestibility of, 115-116
    Hawaiian, 125
  ether extract content of, 113-114
  as fertilizer, use of, 139-140
  gelose content of, 129
  iodine of, form of, 85
  medicinal uses of, agar, 129-130
    in goiter, 111, 115, 116, 120
  nitrogenous constituents of, digestibility of, 116
  protein content of, 113
Algin, definition of, 134
  manufacture of, from kelp, 108
    Hercules Powder Company's process, 137-138
    Stanford's process, 136-137
  properties of, 134-135
  uses of, 138
Alginates, properties of, 135-136
  uses of, 138
Alginic acid, properties of, 134-135
Alimentary canal, of fishes, 212-213
Alligator, description of, 727
Amanori, composition of, 122
  cultivation in Japan, 121
  preparation of, 122
  use of, 122
Amber, 15
Amber-fish, description of, 727
  teeth of, 210
Ambergris, 644
Amino acid concentration, as criterion in determining staleness, 264-265
Anadromous fishes, 216-217
Anchovies, Christiania, 408
  description of, 727
  eggs of, 219
  German delikatessen, 408-409
Anchovy oil, 439
Anchovy paste, 407
Angel-fish, description of, 727
Angler fish-liver oil, 454
Arctic sperm oil, 642
Aroe Islands, pearl fisheries, 170-171
Atka-fish, description of, 727
Australia, pearl fisheries of, 157, 170, 175-176
Autolysis, chemical actions of, 264-265

Autolysis of fish, during cold storage, 281
  during salting, 308, 309
Availability, of fish scrap, as fertilizer, 463-464

B

Bacteria, in canned salmon, 387-389
Bacterial decomposition, of fish, during salting, 308-309
Bagoong, 407
Bahrein Island, pearling fleet, 153, 170
Barracudas, description of, 727
  distribution of, 225
  mouth of, 208
Bass, description of, 727
  sea, ventral fins of, 206
  striped, distribution of, 224, 226
    mouth of, 207
Bath salts, 63, 66, 68
Bating of skins, 502
Bay oil press, 445
Bean trawls, number used, 240, 241
Beluga, description of, 727
Bengal, fish drying in, 371-372
Bill-fish, description of, 727
Bittern, composition of, 64
  recovery of by-products from, 62-69
Blackfish, description of, 727-728
Black shells, 172
Blenny, description of, 728
Blinks, description of, 728
Blister, description of, 728
Blister pearls, 187-189
  nature of, 187-8
  origin, 187
  utilization, 189
Bloaters, description of, 728
  preparation of, 357-358, 359
Blueback, description of, 728
Blue cod, description of, 728
Bluefish, composition, 265-268
  description of, 728
  distribution of, 222-224
  teeth of, 210
Bluefish oil, 439
Blunt-nosed shiner, description of, 728
Boccaccio, 728
Boneless cod, 322
Bonito, canned, statistics, 725
  canning of, 400
  description of, 728
  smoking of, 367
Bonito oil, 439
Boston fish pier, 17
Bouton pearls, 187-188
Bowhead, description of, 728
Brine freezing, of fish, 298-305
    Bull's method, 300
    "Frigus" method, 298
    Ottesen's method, 299-300
    Taylor's method, 301-303
Brine-salting, of fish, 310
Bromine, manufacture of from seaweed ash, 77-78
  recovery of, from bittern, 63, 65, 66
Bug, sand, 563
Bureau of Fisheries, laboratories, 700
Butterfish, 202
  description of, 728
  distribution of, 223
Butterfish-liver oil, 454
Butterfish oil, 439
Buttons, annual production, 180
  manufacture of, 180-183
    American methods, 182-183
    European methods, 181
By-products, from salt manufacture, utilization of, 62-69

C

Cabrilla, description of, 728
Calcium, in salt, for fish salting, 309-310
California, fishery statistics, 720-722
  pearl fisheries of, 156, 177, 178
  salt manufacture in, 39-46
California Press Manufacturing Co.'s fish meal plant, 468-469, 470
Callinectes sapidus, 561
Cameos, mother-of-pearl, 184-185
Canada, fisheries of, 235-236
  fishery trade, 236
Candlefish, description of, 728
Canned fishery products, statistics, 723-726
Cannery, salmon, location of, 381
Canning, of abalones, 617-618
  of fish, 377-403
    the cooking process, 379
    exhausting, 379
    methods, 378-380
    packing, 379
    problems of, 696-697
    processing, 380
    sealing, 379
  of fish flakes, 402
  of herring, 401
  of mackerel, 400
  mussels, 621-622
  of roe, 402
  of sardines, 389-397
  of shad, 401
  of shrimp, 554-558
  of tuna, 397-400
  whale meat, 634-635
Capelin, description of, 728
Carnosine, in fish muscle, 268
Carp oil, 439
Catadromous fishes, 217
Catfishes, description of, 728
  eggs of, 219
Cavalla, description of, 728
Caviar, 409-411
  manufacture in America, 409-410
  manufacture in Russia, 410-411

Cephalopods, 622
Cero, 728
Cetaceans, description of, 728
Ceylon, pearl fishery, 153-155, 170, 177
Chank shells, 178-179, 185
Channel catfish oil, 439
Chicken halibut, description of, 728
China, salt manufacture in, 35-37
  smoked fish industry, 359-360
  smoking of trepang in, 368
Chinook salmon, description of, 728
Chiton, 622, 624
Chogset, description of, 728
Chondrus crispus, botanical characteristics of, 117
Chorda filum, botanical characteristics, 71
Christiania anchovies, 408
Chrome tannage, of sharkskin, 496-497
Chub, description of, 728
Chub mackerel, description of, 728
Clams, 532-547
  bent nose, 533
  butter, 533
  canning, 542-546
    razor clam, 543
  cherry stone, 534, 542
  commercial importance of, 532-533
  composition, 534-535
  contamination of, 535
  culture of, 535-536
  digging of, hard, 537-542
    soft, 536-537
  drying, 546-547
  hard, 534
  list of, 729
  marketing, 537, 542
  Pismo, 532
  razor, 534, 542
  salting, 546
  smoking, 546-547
  soft, life history, 533-534
  species utilized, 532-533
  surf, 532
  Washington, 532
Clam chowder, canning, 546
Clam extract, 546
Clam industry,
  Atlantic Coast, 536-542
  location of, 533
  Pacific Coast, 542
Clam nectar, canning, 543, 545
Clam shells, uses of, 547
Cloth, manufacture from *Posidonia australia,* 144
  sizing of, with algæ, 141
Clupanodonic acid, in fish oils, 417-418
  in whale oil, 637
Coalfish, description of, 729
Coalfish liver oil, 447
Cobia, description of, 729
Cockle, 622, 623
Cod, composition, 269-274
Cod, description of, 729
  distribution of, 223, 226, 228, 233
  fins of, 204, 205
  fisheries, 233
  fishery, gill net, 252
    trawl line methods, 247-248
  food of, 215
  hard-dried, 322-323
  migrations of, 216
  salted, barreled, 326
    boning, 321-322
    curing at home station, 325
    drying, 319-320
    Pacific Coast industry, 323-326
    Pacific Coast vessel fishery, 324
    quantity produced in America, 329
    shore-station methods of preparation, 324-325
    skinning, 320-322
    slack, 323
  salting, 315-326
    butt method, 318-319
    cleaning preparatory to, 317-318
    kench method, 319
    location of industry, 315, 317, 327
    in New England, 317-323
  scales of, 202
  scrap, 462
Cod-liver oil, electrolytic extraction, 445
  industry, 442-443
  manufacture of, 443-445
  medicinal, manufacture of, 443-444
  production of, 443
  properties, 446-449
  refining of, 445-446
  vitamin content, 277-278
Cod oil, uses of, 449-450
Cod roe, smoking of, 368
Cod skin, tannage, 499
Cod tongues, salted, 325-326
Cold-smoking, of fish, 352
Cold storage, of fish, 293-296
    changes during, 282-283
Color, of fishes, 213-215
Commander Islands, fur sealing on, 648, 650
Composition, of fishes, 265-268, 269-271
  of lobsters, 584-585
Conch, description of, 729
Conchiolin, of mother-of-pearl, 168
Conger eel, description of. 729
Connecticut, fishery statistics, 703-707
Copper oleate, use in net preservation, 261
Coral, composition, 192
  economic importance of, 21
  grading of, 196
  living, 191-192
  methods of fishing, 194-196
  nature of, 191
  price of, 199
  utilization in jewelry, 198-199
  working of, 196-199

Coral banks, Algerian, 192-4
  Red Sea, 194
  Sicilian, 193
  Tunis, 192-194
Coral fishing, 192-196
Coral industry, history, 190
  importance of, 190-191
  location of, 192-194
Corallium rubrum, 191-192
Cormorants, use of in fishing, 259-260
Corned river herring, 335
Costa Rica, turtle fishery, 598-599
Court plaster, manufacture of, 491
Crabs, 561-576
  blue, life history, 563-564
    season, 565
  canned, statistics, 726
  canning of, 575-576
  composition of, 564
  fiddler, 562
  green, 562
  hard, fishery, 567-569
    preparation for market, 571-573
    steaming, 571-572
  hermit, 562
  horseshoe, 562
  Jonah, 561, 562
  kelp, 562
  king, 562
  lady, 562
  list of, 729
  marketing, 568-569
  mud, 562
  mussel, 562
  oyster, 563
  purple shore, 563
  red, 563
  rock, 561, 563
  soft, fishery, 565-567
    preparation for market, 569-571
    season, 565
  species utilized, 561-563
  spider, 563
  stone, 562, 563
  yellow shore, 563
Crab dredges, number used, 240, 241
Crab-eater, description of, 729
Crab fishery, Atlantic Coast, 564-573
  methods, 565-569
  Pacific Coast, 573-575
Crab industry, statistics, 561-562
Crab scrapes, 565-567
  number used, 240-241
Crab shells, utilization of, 573, 576
Crab traps, number used, 240, 241
Cramp-fish oil, 439
Crawfish, sea, 593-594
Creatine, in fish muscle, 268
Creatinine, in fish muscle, 268
Crevallés, description of, 729
  distribution of, 224
Croaker, description of, 729
  voice of, 212
Croaker oil, 439
Crustacea, economic importance of, 20
Cultch, definition of, 729
Cultus cod, description of, 729
Cuneata clam, description of, 729
Curb, for pressing fish, 422-423
Currying, of leather, 450
Cusk, description of, 729
  distribution of, 223
  salted, 323
Cusk-liver oil, 454
Cuttlefish, description of, 729
Cuttlefish-liver oil, 454

D

Degras, manufacture of, 430
Dehydrated fish, characteristics of, 376
  composition of, 376
  storage of, 371
Dehydration, of fish, 368-376
    in Germany, 374
    modern process, 374-376
    principles of, 369-371
    Scott's process, 374-376
Delaware, fishery statistics, 708-709
Delikatessen, German, 408-409
Demersal eggs, 219
Destructive distillation of seaweed, 78-9, 102-104, 105
Diving, for pearls, 151-153, 174
  machine, sponge fishery, 684-686
Dogfish, description of, 729
  utilization of, 692
Dogfish-liver oil, 447, 453, 454
  properties, 453, 454
Dogfish scrap, 462
Dolphins, 644-646
  description of, 730
Dolphin-jaw oil, 645
Dolphin oil, 645
Donax, 622, 623-624
Dredges, oyster, 521-522
  scallop, 613
Dredging, for scallops, 608, 612
Drum, black, distribution of, 222
    food of, 215
    teeth of, 210
  description of, 730
Drying, of shrimp, 558-560
Dry-salting, of fish, 310-311
Dulse, 120
Dun-fish, description of, 730
Duplicator rolls, manufacture of, from algæ, 145

E

Ecklonia bicyclis, composition of, 84, 85
Ecklonia cava, composition of, 84, 85, 86
Eel, conger, fins of, 204
  description of, 730

- Eel, larval development of, 220
  - smoking of, 366-367
- Eelgrass, industry, 143-144
  - uses of, 144
- Eel-liver oil, 454
- Eel oil, 439
- Eel pots, number used, 240-241
  - use of, 255, 258
- Eelpout, fins of, 206
  - ventral fins of, 206
- Eggs, fish, demersal, 219
    - pelagic, 219
- *Egregia lævigata,* composition of, 95
- *Egregia menziesii,* composition of, 95, 98
- Electrolytic extraction, cod-liver oil, 445
- Epinephrin, 644
- Erucic acid, in fish oils, 417
- Eulachon, description of, 730
- Europe, salt manufacture in, 37-39
- Evolution, evidence of in whales, 625
- Exports, fish, American, 234, 236
- Extraction process, fish meal, 466-467
  - for sardine oil, 432-433
- Eyes, of fishes, 210-211

F

- Fats, rancidity of, 265
  - rusting of, 265
- Fertilizers, fish scrap, 456-464
  - mixed, use of, 464
  - from mussels, 622
- Fiji, pearl shell fisheries, 173, 174, 177
- Filter press, for gurry, 426-427
- Finback, description of, 730
- Finnan haddie, 361-363
  - American cure, 362-363
- Fins, anal, 205
  - caudal, 205
  - function of, 207
  - nature of, 203-207
  - pectoral, 206-207
  - regeneration of, 207
  - ventral, 206
- Fish, abundance of, 18
  - anatomy of, 201
  - annual catch, 227
  - ash, composition of, 274
  - bacterial invasion, 281-282
  - body covering of, 202
  - brine freezing of, 298-305
    - Taylor's method, 301-303
  - brine-salting, 310
  - canned, composition of, 396
  - canning of, 377-403
    - the brining operation, 378-380
    - cans used, 378, 379
    - cleaning of fish, 378
    - early, 377
    - exhausting, 379
    - packing, 379
    - processing, 380
- Fish, sealing cans, 379
  - canning industry, 377
  - capture of, with various gear, 256-257
  - changes during cold storage, 282-283
  - changes during freezing, 282-283
  - composition, fat content, 265-268, 269-271
    - seasonal variation, 265-268
  - constituents of, nature, 268-275
  - definition of, 200
  - dehydrating, problems of, 696
  - digestibility of, 275-276
  - drying of, in Bengal, 371-372
    - in Germany, 374
    - in Hawaii, 373-374
    - in Japan, 372-373
    - oriental methods, 371-374
    - primitive, 368-369
  - dry-salting, 310-311
  - exports of, 234, 236
  - fermented, 407
  - flesh, form of nitrogen in, 268, 272-274
    - hydrogen ion concentration of, 264
    - nitrogenous constituents, 268, 272-274
  - food of, 18-20
  - form of, 200
  - freezing, in air, 285-293
    - in brine, 693-694
    - inspection, 286-287
    - internal crystallization of water during, 282
    - panning, 288
    - preliminary handling of fish, 285-286
    - in sharp freezer, 288-290
  - freezing plants, 283-285
    - construction of, 283-285
    - layout, 283-285
    - mechanical equipment of, 284-285
  - fresh, appearance of, 263, 264
    - characteristics of, 286-287
    - chemical characteristics, 264-265
    - color of gills, 263, 264
    - condition of kidney, 263
    - discoloration as staleness approaches, 263, 264
    - firmness of flesh, 263, 264
    - physical characteristics of, 263-264
  - frozen, cold storage of, 293-296
    - cooking of, 297-298
    - defrosting, 297-298
    - desiccation of, 282, 295-296
    - glazing of, 291-293
    - loss of flavor, 282
    - packing of, 296
    - rusting of, 282-283, 295-296
    - shipment of, 296-297
    - statistics, 280-281
  - imports of, 234-235, 236
  - marinated, 404-407
    - fried, 405-406

Fish, methods of salting, 310-311
  nutritive value of, 275-279
  oils, 415-441
  pickled, Japanese, 407
  preservation of, miscellaneous processes, 404-414
  proteins, nutritive value of, 278
  proximate composition, 265-268, 269-271
  pudding, 413
  putrefaction of, 281-282
  refrigeration, importance of, 280-281
  salted, miscellaneous, 345-346
    reddening of, 313-314
    rusting, 312-314
    storage of, 311-314
    U. S. A. statistics, 329
  salting, autolysis during, 308-309
    location of, 327
    methods of cleaning, 311-312
    principles of, 307-315
    in warm climates, 314-315
  sausages, 407-408
  scrap, composition, 462-463
    fertilizer, availability, 463-464
  smoked, statistics, 349, 353, 354, 361, 363
  smoking of, 348-368
    chemistry of, 352-353
    in China, 359-360
    cold-smoking, 352
    hot-smoking, 352
    the industry, 348, 349, 361
    in Philippine Islands, 359-360
    problems of, 696
    processes, 352, 353
    in Scotland, 348
    woods, used, 351-352
  stale, odor of, 263, 264
  washing of for freezing, 287
  vitamin content, 276-279
Fisheries, British, importance of, 227, 228, 229, 236-237
  Canadian, 235-236
  early importance of, 15, 229
  French, importance of, 227, 228, 229
  Gulf States, statistics, 716-719
  Japanese, importance of, 16, 18, 227, 228, 229, 237-238
  New England, statistics of, 703-707
  Newfoundland, importance of, 18
  Norwegian, importance of, 227, 228, 229, 237
  Nova Scotia, importance of, 18, 227, 228
  Pacific Coast States, statistics, 720-722
  South Atlantic States, statistics, 712-715
  Spanish, importance of, 227, 228, 229
  United States, importance of, 227, 228, 229, 230-235
    statistics of, 703-726
  value of, 227-230
Fishermen, American, 229
Fishery industries, problems of, 692-702
Fishes, alimentary canal of, 212-213
  of Atlantic Coast, 221-224
  carnivorous, 215-216
  color, 213-215
  eggs, demersal, 219
    incubation of, 220
    pelagic, 219
  extermination of, 220-221
  eyes of, 210-211
  food, utilization of, 692-693
  foods of, 215-216
  geographical distribution of, 217, 221-226, 227-228
  gills of, 212
  of Gulf Coast, 224
  hearing of, 211
  herbivorous, 215-216
  larval development, 220
  lateral line of, 211
  lungs of, 212
  markings of, 215
  migrations, 216-217
  nostrils of, 211
  omnivorous, 215-216
  of Pacific Coast, 224-226
  protection of, 221
  reproduction of, 218-220
  spawning of, 218-220
  tactile organs of, 211
  voice of, 212
Fish cannery, heat for, 378
Fish flakes, canning of, 402
Fish glue, 476-487
  ash content, 484
  by-products, 486
  color, 485
  drying properties, 484
  gel point, 483
  hygroscopic properties, 485
  the industry, 476
  joint strength, 485
  manufacture of, 477-481
    chemistry of, 476
  moisture in, 484
  raw materials, 476
  speed of set, 484
  uses, 487
  viscosity, 484
Fishing rights, disputes concerning, 15
Fish lines, number used, 240-241
Fish meal, 465-474
  by-product from glue manufacture, 486-487
  composition of, 471-472
  industry, 465
  manufacture of, 466-471
    California Press, 468-469
    extraction process, 466-467
    Hiller process, 469
    press method, 466
    vacuum process, 467-468

Fish meal, nutritive value, 472-474
  plants, efficiency of, 469-471
  storage, 471
  use, 474
Fish proteins, composition of, 693
  hydrolytic products, 273-274
Fish roe, composition of, 275
Fish scrap, manufacture of, oriental methods, 457, 458
Fish waste, utilization of, 698-699
Fish wheels, number used, 240-241
Flakes, for drying of salted cod, 319-320
Flatfish, description of, 730
Florida, fishery statistics, 712-719
Flounders, color of, 213-214
  description of, 730
  distribution of, 221, 224
  form of 201
Flounder oil, 439
Flying fish, 208
Foods, of fish, 215-216
France, sardine industry of, 397
Freezers, defrosting pipes of, 290
  sharp, temperature of, 289-290
Freezing, of fish, changes during, 282-283
Freshness, of fish, chemical characteristics of, 264-265
Fucus alaria, composition, 81
Fucus nodosus, botanical characteristics, 71
  composition of, 73, 75, 81
Fucus serratus, botanical characteristics, 71
  composition of, 73, 74, 75, 81
Fucus siliquosus, botanical characteristics, 71
  composition of, 81
Fucus stenolobus, composition of, 81
Fucus vesiculosus, botanical characteristics, 71
  composition of, 73, 74, 75, 81
  medicinal use, in prevention of goiter, 120
Funori, manufacture, Japanese, 142-143
  uses, 143
Fur seal, description of, 730
Fur sealing, history of, 647
  pelagic, 650-651
  in Southern Hemisphere, 647-648
Fyke nets, number used, 240, 241
  use of, 255

G

Gagova, 686-688
Gambusia, anal fin of, 205-206
  eyes of, 211
  fins of, 205-206
  reproduction of, 219
Gangava, 686-688
Garfish, description of, 730
Garrupa, description of, 730
Gasoline, use in extraction of sardine oil, 432-433
Gaspereau, description of, 730
Gear, fishery, British, 259
    Canadian, 259
    foreign, 259-260
    German, 259
    Japanese, 259
    Mediterranean, 259
    relative importance, 241-242, 256-258
    Swedish, 259
    United States, value of, 229, 230, 239-241
Georgia, fishery statistics, 712-715
Gill-cover, 212
Gill nets, number used, 240, 241
  salmon, 252
  use of, 251-253
Gill-rakers, 212
Gills, of fishes, 212
Gill-slits, 212
Gizzard shad, description of, 730
Glazing, of frozen fish, 291-293
Globefish-liver oil, 454
Gloucester harbor, 17
Glue, from abalones, 618
  cookers, 479, 481
  fish, 476-487
    composition, 481-483
    examination of, 483-486
    gel point, 483
    sources of, 699
  fish head, manufacture, 481
  seaweed, 142-143
  skin, manufacture, 477-480
  waste, manufacture of, 480-481
  whale, 644
Glue liquor, evaporation of, 479-480
Glycogen, in oysters, 528
Goby, food of, 216
Goiter, algæ as preventative of, 111, 115, 116, 120
Gold, in sea water, 24, 27
Goldfish, description of, 730
Goosefish, description of, 730
Grampus, description of, 730
Gray whale, description of, 730
Great Britain, fisheries, 236-237
Green-fish, description of, 730
Green snails, 173-174
Green turtle, description of, 730
Grilse, description of, 730
Grouper, description of, 733
Grunt, description, 731
Guanin, in pearl essence, 162, 163, 165
Guitar fish-liver oil, 454
Gurry, menhaden oil, 425-427
  menhaden oil, recovery of, 426-427

H

Haddock, description of, 731
  distribution of, 223, 228, 233
  fisheries, 233

Haddock, fishery, otter trawl, 254-255
    trawl line methods, 247-248
  salted, 323
    quantity prepared in the United States, 329
  smoked, 361-363
Haddock-liver oil, 447
Haddock oil, 439
Hake, description of, 731
  distribution of, 223
  salted, 323
Hake-liver oil, 447
Halibut, composition of, 269-274
  description of, 731
  distribution of, 223, 225-226, 233
  fisheries, 233
  fishery, trawl line methods, 248
  smoking of, 365-366
Halibut leather, 499-500
Harpoon gun, 630
Harvester, kelp, 96-97
Hawaii, edible algæ of, 125
  fish drying in, 373-374
Hawk'sbill turtle, description of, 731
Hawk'sbill turtle fishery, 599-600
Hercules Powder Company's kelp plant, 106
Herring, Bismarck, 406-407
  canning of, 400-401
  description of, 731
  distribution of, 222, 228, 233
  fisheries, 233
  Kaiser-Friedrich, 406
  marinated, 404-407
  mustard, 406
  salted, location of industry, 328
    quantity prepared in the United States, 329
  salting, American methods, 328-331
    by American "Scotch cure," 330-331
    in Holland, 332-333
    in Norway, 331-332
    in Scotland, 331
  smoked, bloaters, 357-358, 359
    boning, 357
    brining, 354-355
    grading of, 357
    kippering, 358, 359
  smoking of, 353-360
    American methods, 353-358
    hard herring, 353-357
    processes, 353
    red herring, 353-357
    in Scotland, 359
Herring horses, 355
Herring oil, 430-435
  composition, 435
Himanthalia lorea, botanical characteristics, 71
  composition of, 81
Histidine, in fish muscle, 268
Hogfish, description of, 731
Hoi oil, 439
Holland, eelgrass industry of, 143-144
  smoked fish industry, 359
Hoop nets, number used, 240, 241
Horsefish, description of, 731
Horsefoot, description of, 731
Horsehead, larval development of 220
Horse-mackerel, description of, 731
Horseshoe crab, description of, 731
Hot-smoking, of fish, 352
Humpback, description of, 731
Hypoxanthine, 268

I

Ichthylepidin, in fish scales, 476
Imidazo-ethylamine, in fish, 272
Imports, fish, American, 234-235, 236
Ingegno, use in coral fishing, 195
Inlaid objects, manufacture of, 184
Insulin, 693
Iodine, manufacture of, from seaweed ash, 77, 78, 80, 81-82, 86
  in sea water, 24
Iodine industry, French, 79
  Japanese, 82-6
    location of, 83
Iridæa sp., composition of, 95, 98
Irish moss, curing, 118-120
  European industry, 120
  industry, 117-120
  properties of, 117-118
  Scituate, Mass. industry, 118
  uses, 120, 141
    as size, 141
  washing, 119
Iron chink, 382-383
Isinglass, 487-491
  composition of, 490
  manufacture of, 488-489
  properties of, 489-490
  raw materials for manufacture of, 487
  uses, 491
Italy, coral industry of, 196-199
  salt manufacture in, 37-39
Ivory, walrus, 666

J

Jack, description of, 731
Japan, bonito smoking in, 367
  clam cultivation in, 536
  coral fishing in, 195-196
  fish drying in, 372-373
  fisheries, 237-238
  importance of fisheries in, 16, 18
  manufacture of fish oil in, 434
  salted mackerel industry, 339-340
  salted salmon industry, 344
  salt manufacture in, 33-37
Japanese, pearl shell fishery, 178
Jewel, description of, 731
Jurel, description of, 731

K

Kelp, as animal feed, 97
  ashes, lixiviation of, 77, 78, 81, 82, 86
  beds, extent of, 89-90
  definition of, 70
  destructive distillation of, 102-104, 105
  destructive distillation products, 105
  fermentation of, 104, 106-110
  as fertilizer, value of, 99-100
  form of nitrogen in, 98
  harvesting, early methods, 88, 89
  incineration of, 101
  industry, future of, 108-110
  pneumatocyst, gas in, composition of, 94
Kelp, species on Pacific Coast, 89
Kelpchar, manufacture of, from kelp, 104
Kemp's Gulf turtle, 601
Kench method, of salting cod, 319
Key West, turtle fishery, 597-598
Killer whale, description of, 732
Kingfish, description of, 732
Kingfish oil, 439
Kippered herring, 358, 359
  canning of, 401
Kippered salmon, 364-365
Kombu, industry, 123-124
  preparation of, 123-124

L

Ladyfish, description of, 732
Laminaria andersonii, composition of, 95, 98
Laminaria angustata, composition of, 84
Laminaria bulbosa, botanical characteristics, 71
  composition, 81
Laminaria digitata, botanical characteristics, 71
  composition of, 73, 74, 75, 81
Laminaria japonica, composition of, 84
Laminaria longissima, composition of, 84
Laminaria ochotensis, composition of, 84
Laminaria saccharina, botanical characteristics, 71
  composition of, 73, 81
Laminaria stenophylla, botanical characteristics, 71
  composition of, 74, 75, 81
Lamprey, description of, 732
Lant, description of, 732
Larvæ, of fishes, 220
Lateral line, 211
Laurencia pinnatifida, use as condiment, 121
Leather, 492-503
  dyeing, 503
  finishing, 503
Leathery turtle, 601
Leucine, in fish, 272
Lime ponds, 43-44
Liming, of skins, 502
Lines, fish, use of, 245-248
  hand, use of, 245-246
Ling, description of, 732
Ling-liver oil, 447
Ling oil, 439
Lingah shells, 153, 177
  French imports, 167
Liver oils, 442-455
  characteristics of, 442
Lobsters, 577-595
  boiling of, 591
  canning of, 592-593
  color of, 582
  composition, 584-585
  description of, 732
  habits, 581-582
  life history of, 579-582
  live, preservation of, 588-590
    transportation of, 590, 591
  propagation of, 582-584
  species of European, 594-595
  spiny, American industry, 593-594
Lobster bait, 587-588
Lobster fishery, Canadian, 591-592
  European, 594-595
  history of, 577-578
  location of, 577
  New England, 586-591
  Newfoundland, 591-592
  statistics of, 578, 586, 595
Lobster pots, 586-587
  number used, 240, 241
Lobster shells, composition, 585
Loggerhead, description of, 732
Loggerhead turtle, 600-601
Louisiana, fishery statistics, 716-719
Lump-fish, description of, 732
Lungs, of fishes, 212
Luth turtle, 601

M

Macassar, pearl shell fisheries, 171, 176-7
Mackerel, on Atlantic Coast, 222
  canning of, 400
  description of, 732
  distribution of, 222, 224, 228
  fins of, 204
  Japanese methods of salting, 339
  salted, grades of, 339
    quantity prepared in America, 329
    repacking of, 338-339
  salting of, 335-340
    on board schooners, 337-338
  smoking of, 366
  Spanish, composition, 265-268
Mackerel oil, 439
Mackerel pike oil, 439
Macrocystis pyrifera, botanical characteristics of, 91

Macrocystis pyrifera, composition of, 93-5, 98
Magnesium, metallic, preparation from bittern, 66
  in salt, for fish salting, 309-310
Magnesium oxychloride cements, 63, 66, 68
Magnesium sulphate, recovery of, from bittern, 65
Maine, fishery statistics, 703-707
Malaysia, pearl fishery of, 157-158
Manatee, description of, 732
Manila shells, 171
Manna, manufacture of, from laminaria, 145
Margaritifera vulgaris, geographical distribution, 169
Margate-fish, description of, 732
Marichchikadde, pearl fisheries, 154
Marinated herring, canning of, 401
Marine products, possibilities of, 23
  value of, world's, 16
Maryland, fishery statistics, 710-711
Massachusetts, fishery statistics, 703-707
Mattowacca, description of, 732
Mattresses, eelgrass, 144
Medialuna, description of, 732
Mellon Institute of Industrial Research, laboratories of, 701
Menhaden, capture of, 244-245
  cooking, 421-422
  description of, 732
  distribution of, 222, 224
  fish scrap, 456, 458-460
    production of, 457
  fishing, 419-421
  fishing season, 419
  fish meal, composition of, 471-472
  food of, 215
  gills of, 212
  migrations of, 217
  pressing, 422-424
  press water, utilization of, 698-699
  scales, use in preparation of pearl essence, 162
  scrap, composition, 462
    drying of, 457-459
  unloading, 421
Menhaden oil, 418-430
  composition of, 429
  grades of, 428
  location of industry, 418-419
  manufacture, 421-427
  refining of, 428
  separation of, 424-425
  uses, 429-430
  vitamin content, 277
  yield of, 427
Menhaden steamer, 244
Mergui shells, 171
Merluccio, description of, 732
Mexico, pearl fisheries of, 156
Mild-curing, of salmon, 341-343
Milt sauce, for marinated fish, 406-407
Minnow, top, anal fin of, 205-206
  sight of, 211
Mississippi, fishery statistics, 716-719
Mollusks, economic importance of, 20
Moonfish, description of, 732
Moresby shells, 171
Mosaic, mother-of-pearl, 185
Mother-of-pearl, composition, 168-169
  grading of, 179-180
  preservation of, 186-187
  structure, 168-169
  use of, by savages, 167
  utilization of, 180-186
  working of, 180-186
Mother-of-pearl fisheries, species utilized, 169
Mother-of-pearl jewelry, 185
Mouth, of fishes, 207-208
    inferior, 208
    superior, 208
Mullet, alimentary canal of, 213
  brine-salted, 345
  description of, 732
  distribution of, 223, 224
  fins of, 203
  kench-cured, 345
  larval development of, 220
  mouth of, 207
  salted, industry, 344-345
  teeth of, 209
Mullet roes, dried, 411, 413
Mummichog, description of, 733
Murlins, use as food, 121
Mussels, canning of, 621-622
  characteristics of, 619
  as chicken feed, 622
  composition of, 620
  description, 733
  fishing for, 620
  industry, European, 619
  industry, statistics of, 618-619
  pickled, 621
  sea, 618-622
    species utilized, 619
  shells, mother-of-pearl, 172
  use as bait, 622
  utilization of, 620-622
Mutton-fish, description of, 733

N

Narwhal, description of, 733
Natica, 622, 623
National Canners Association, laboratories, 701
Necklace, pearl, evaluation of, 159
  pearl, string of, 160
Nereocystis leutkeana, botanical characteristics of, 91
  composition of, 93-5, 98
Net, preservation, 260-261

Net lifters, use of, 252
Netherlands East Indies, pearl fisheries, 171, 176-7
Nettings, fish, domestic production, 258-259
New Caledonia, pearl shell fisheries, 176
Newfoundland, importance of fisheries in, 18
New Hampshire, fishery statistics, 703-707
New Jersey, fishery statistics of, 708-709
New York, fishery statistics, 708-709
Nitrocellulose lacquer, use in pearl essence, 162, 164, 165
North Carolina, fishery statistics, 712-715
Norway, cure of herring, 331-332
  fisheries of, 237
  importance of fisheries in, 18
  sardine industry, 395-397
Nova Scotia, importance of fisheries in, 18

O

Ocean, age of, 26-27
Octopus, fishery, 624
Oil, arctic sperm, 642
  for canning sardines, 395
  cod-liver, vitamin concentrate from, 698
  fish, composition of, 429
  menhaden, 418-430
  seal, 663-664
  shark-liver, problems of, 698
  sperm, 637-640
  walrus, 666-667
  whale, 635-637, 638
Oils, decolorization of, 697
  deodorization of, 697-698
  fish, 415-441
    characteristics, 415-418
    detection of, 417-418
    production of, 416, 420, 421, 430, 436
  hydrogenated, 429-430
  hydrogenation of, 697-698
  liver, 442-455
Oregon, fishery statistics, 720-722
Otter, description of, 733
Otter trawls, construction of, 254-255
  number used, 240, 241
  for shrimp, 552-553
Oviparous species of fishes, 219
Oyster, description of, 733
  fisheries, 232-233, 506-513
    African, 511
    American, 506-508, 513
    of Asia, 510-511
    Australia, 511
    British, 509-510
    Canadian, 508
    Chinese, 510
    European, 509-510
Oyster, fisheries, French, 509
    Holland, 510
    India, 511
    Japanese, 510
    Mexican, 508-509
    New Zealand, 511
    Philippine Islands, 511
    of South America, 508-509
    statistics, 511-513
    world's, 512
Oyster industry, development of, 504-505
  primitive, 504
Oyster shells, composition, 529
Oysters, 504-531
  by-products, 527
  canned, statistics, 726
  canning, 526-527
  composition, 528, 529
  conditioning, 517-519
  disinfection of, 530
  dredging of, 521-522
  drying, 527
  enemies, 516
  factors of environment, 515
  food of, 515
  grading, 524
  grit, 527
  growing of, 514-519
  habitat, 515
    bottom, 516
    influence of silt, 516
    influence of trade wastes, 515-516
    salinity, 515
  infection from eating, 530
  life history, 514
  marketing, 523-526
  salting, 527
  shell stock, 525-526
  shipment of, 524-526
  shucking, 523-524
  spat collecting, 516-517
  taking of, 519-522
  tonging, 519, 521
  unloading, 522-523
  washing, 524

P

Paint, manufacture of, from menhaden oil, 430
Panama, fishes of, 218
  pearl fisheries of, 155-156, 172
Paper, from eelgrass, 144
  from seaweeds, 144
Paranzella nets, number used, 240, 241
  use of, 255
Parrot fish, color of, 214-215
Paste, anchovy, 407
Pearl, beauty of, 146
Pearl essence, 161-166
  levigation of, 163
  nature of, 162

Pearl essence, preparation of, 162-166
  properties of, 162-164
  purification of, 165
Pearl fisheries, of California, 156, 174, 177-178
  in Ceylon, 153-155, 170, 177
  importance of, 148
  Macassar, 176
  of Malaysia, 157-158
  methods, 151-153, 174
  of Mexico, 155
  native diving, 151-152, 174
  Netherlands East Indies, 171, 176-7
  of Panama, 155-156
  in Persian Gulf, 152-153, 170, 177
  Philippine, 176
  in Red Sea, 155, 170, 172
  scaphander diving, 152, 174
  Thursday Island, 170
  Venezuelan, 153, 170, 177
Pearl oyster, description of, 733
  fisheries, location, 169-170
  shells, classification, 179
Pearl rings, mounting, 160
Pearl shells, British imports, 168
  classification of, 179-180
  commerce in, 167-168
  fisheries, India, 178
  French imports, 167
  margaritifera,
    black shells, 172-173
    green shells, 172
    white shells, 170-171
    yellow shells, 171-172
  species utilized, 169
  structure, 168-169
Pearls, black, 158
  blister, 187-189
    nature of, 187-8
    origin, 187
  brown, 158
  cleaning of, 150-151
  composition of, 150
  drilling, 159-160
  evaluation of, 158-159
  form of, 158-159
  growth of, 148-150
  imitation, early manufacture of, 161-162
    indestructible, 161-162, 164
    manufacture of, 161-165
  importance in history, 146-147
  mounting, 160
  noted American, 147-148
  origin of, 148-150
  pink, 158
  preservation of, 150-151
  properties of, 150-151
  red, 158
  stringing, 160
  structure of, 150
  value of, 20
Pelagic eggs, 219
Pelagophycus porra, composition of, 95, 98
Pennsylvania, fishery statistics, 708-709
Periwinkle, 622, 623
  description of, 733
Persian Gulf, pearl fishery, 152-153, 170, 177
Philippine Islands, pearl fisheries, 176
  salt manufacture in, 33-35, 36-37
  smoked fish industry, 359, 360
  smoking of trepang in, 368
Photo-engraving glue, 480
Pickling, of salmon, 343
Piddock, 622, 623
Pigfish, description of, 733
Pilchard oil, 439
Pilot-fish, description of, 733
Pinfish, description of, 733
Pink pearls, 158
Pink yeast, in oysters, 529
Pipe fishes, mouth of, 208
  regeneration of fins, 207
  reproduction of, 219
Plaice, description of, 733
Plankton, 19-20
Pogy, description of, 733
Pollack, description of, 733
  salted, 323
Pollack oil, 439
Pollution, effect on fish life, 216
Pompano, description of, 733
Porcupine-fish, body covering of, 203
  form of, 202
Porgee, description of, 733
Porgy oil, 439
Pork-fish, description of, 734
Porphyra laciniata, use in British Isles, 120
Porpoises, 644-646
  description of, 734
Porpoise-jaw oil, 646
Porpoise leather, 499, 501
Porpoise oil, 646
Potash, manufacture of, by incineration of kelp, 100-102
  produced in U. S. A. during war, 90
Potassium chloride, manufacture of, from bittern, Balard's process, 63, 67
    California process, 68-69
Potassium salts, manufacture of, from seaweed ash, 77, 78, 80, 81, 82, 86
  recovery of, from bittern, 62-69
Pots, number used, 240, 241
Poultry feed, 486-487
Pound nets, Great Lakes, 250
  number used, 240, 241
  use of, 248-251
Preservation, net, 260-261
Presses, fish, screw, 423-424
Pribilof Islands, fur sealing on, 648-650, 653-655
Problems, of fishery industries, 692-702

Pudding, fish, 413
Puffers, form of, 202
Pusher, for scallops, 611-612

Q

Quahang, description of, 734
Queen-fish, description of, 734
Queensland, pearl fisheries of, 175-176
Quinnat, description of, 734

R

Racer, description of, 734
Radium, in sea water, 24, 27
Rake, basket, for clams, 540
  claw, for clams, 539
Rancidity, estimation of, 265
Ratfish-liver oil, 454
Rays, description of, 734
  eggs of, 219
  teeth of, 209, 210
Ray skin, tannage, 499
Razor clam, description of, 734
Razor-shell, description of, 734
Reddening, salted fish, 313-314, 694-695
Red drum, description of, 734
Red-eye, description of, 734
Redfish, description of, 734
Red horse, description of, 734
Red Sea, pearl fisheries of, 155, 170, 172
Red snapper, description of, 734
Refrigeration, of fish, 280-306
Refrigeration machines, 284-285
Remoras, mouth of, 208
Rhode Island, fishery statistics, 703-707
Rigor mortis, criterion of freshness of fish, 263, 264, 281
Robben Island, fur sealing on, 648, 650
Robin, description of, 734
Rock bass, description of, 734
Rockfish, description of, 734
  distribution of, 225
  fishery, trawl line methods, 248
Rock trout, description of, 734
Roe, canning of, 402
  composition of, 275
  dried mullet, 411, 413
Roncador, description of, 734
Rosefish, description of, 734
Round robin, description of, 734
Rubber compounds, manufacture of, from algæ, 145
Rudder-fishes, description of, 734
  food of, 215
Runner, description of, 734
Russia, caviar manufacture in, 410-411
  fur sealing in, 648-650
  manufacture of isinglass in, 488-489
Rusting, of fresh fish, 265
  of frozen fish, 282-283
  of salted fish, 312-314, 695-696

S

Sailor's choice, description of, 735
Salmon, bacteriological examination of canned, 386, 388, 389
  canned, composition, 386-387
    grades of, 386
    physical examination of, 386
    quantity and value, 380
    statistics, 723-724
  canning, exhausting, 385
  canning industry, 380-389
  canning process, 381-385
  capture of, 381
  common and scientific names of, 385
  description of, 735
  distribution of, 226, 228, 230-232
  eggs, 220
  fisheries, 230-232
  fishery, gill net, 252
    hand line, 246
  fish meal, composition, 472
  kippered, 364-365
  salted, importance of industry, 340
    Japanese methods of preparing, 344
    mild-curing, 341-343
    pickling, 343
    Siberian methods of preparing, 344
  salting of, 340-344
  scrap, manufacture, 460-461
  smoking of, 363-365
    in Germany, 365
Salmon oil, 436-438
  characteristics of, 437
  manufacture of, 436-437
  pressing, 436-437
  separation of, 437
  uses, 437
  vitamin content, 277
Salmon roe, composition, 275
Salmon skin, 499-500
Salmon traps, floating, 251
Salmon waste, utilization of, 698
Salt, in brine, recovery of, 694
  by-products of, economic importance of, 22
  composition of, influence on rate of penetration of salt into fish, 309-310
  dairy, 30, 47, 62
  economic importance of, 21-22
  grades of, 30, 31, 62
  grainer, structure of, 53-54, 55
  ground alum, 30
  harvesting, 40-41, 45
  industry, importance of, 31
    location of, 31
  manufacture of, in China, 35-37
    early European, 28-29
    by European solar salt process, 37-39
    by improved oriental solar process, 36-37
    in Japan, 33-37

Salt, manufacture of, by oriental leaching process, 32-35
    by oriental solar process, 35-36
    in Philippines, 33-35, 36-37
    processes, 32-46
  in ocean, source of, 26
  packers, 30, 62
  properties of, 29-31, 47-8
  sea, composition of, 47-48
  solar, structure of, 51, 56
  table, 30, 47, 62
  uses of, 30, 31
  vacuum pan, 52
Salt bittern, utilization of, Balard's process, 63, 67
Salt grainer, 58-59
Salt refining, 47-62
  in grainers, 57-59
  principles of, 49-56
  by rewashing, 56-57
  in vacuum pan, 60
Salted fish, reddening of, 694-695
Salting, of cod, 315-326
    New England methods, 317-323
Sand-dab, description of, 735
Sardines, California industry, 391
  canned, bacteriology of, 394-395
    composition of, 396
    statistics, 725
  canning of, drying process, 389, 393
    in France, 395-397
    frying, 391
    in Norway, 395-397
    oil for, 395
    in tomato sauce, 391
  canning methods, 389-394
  capture of, in California, 394
    in Maine, 389
  chemistry of, 394-395
  conveyor for, 392
  definition of, 389
  description of, 735
  distribution of, 225
  Maine industry, 389
  marinated, 405
  scaling machine, 392
  smoking of, in Norway, 396
  Russian, 405
Sardine oil, 430-435
  characteristics of, 433-434
  extraction of, 432-433
  Japanese, characteristics, 434-435
    manufacture of, 434
  manufacture of, 431-434
  separation of, 431
  yield of, 432
Sardine scrap, composition, 462
Sargassum sp., composition of, 84
Sausages, fish, 407-408
Sawfish, fins of, 205
Sawfish-liver oil, 454
Scales, ctenoid, 202
  cycloid, 202
Scallops, 607-615
  composition, 609-610
  description of, 735
  giant, fishery, 615
  life history, 608-609
  marketing of, 612, 614
  species of, 608-609
Scallop fishery, 610-615
Scallop industry, statistics, 607
Scallop shells, utilization of, 614
Scaphander, in pearl fisheries, 152, 174
  in sponge fishery, 684-686
Schooner, invention of, 16
  used in trawl line fishery, 247
Scorpions, description of, 735
Scotch cure, of herring, 330-331
Scotland, cure of finnan haddie, 361-362
  smoked fish industry, 359, 361-362
Sculpin, description of, 735
Scup, description of, 735
  distribution of, 223
Scup-liver oil, 454
Sea, extent of, 15
Sea bass, description of, 735
  fins of, 206
Sea bass oil, 439
Sea elephant, California, 661
  description of, 735
  southern, 661
  species, 661
Sea herring, description of, 735
Sea-horse, description of, 735
Seal, bearded, 660
  Caspian, 661
  crab-eating, 661
  crested, 661
  description of, 735
  gray, 660
  harbor, 660
  harp, 660
  hooded, 661
  Lake Baikal, 661
  leopard, 660, 661
  monk, 661
  ribbon, 660
  ringed, 660
  Ross', 661
  Weddell's, 661
  West Indian, 661
Seal industry, by-products, 660
Sealing, pelagic, 650-651
Seals, economic importance of, 20
  fur, 647-660
    classification of pelts, 656-657
    disposition of carcasses, 655
    federal protection, 654
    habits, 652-653
    handling of pelts, 655
    killing, 654
    preparation of the fur, 657-660
    sealskins, dyeing of, 658
    skinning, 654
    species of, 651-652

Seals, hair, habits, 661
    hunting, 662
    industry, 662-664
    species of economic importance, 660-661
Seal oil, composition, 663-664
  preparation of, 663
  properties, 663-664
Sea lions, description of, 735
  species of, 661
  use for leather, 492-493
Sealskins, fur, tanning of, 658
Sealskin leather, 492-494
Sea mussels, 618-622
Sea robin, description of, 735
Sea snails, description of, 735
Seatron, 120
Sea trout, description of, 736
Sea water, composition of, 24-27
Seaweeds, as animal feed, 97, 140-141
  ash of, composition of, British, 78
      French, 80
      Japanese, 86
    utilization of, in eighteenth century, 72
  burning, 76, 77, 80, 84, 86, 101
  destructive distillation of, 78, 79, 102-104
  drying of, 76, 80, 84, 97, 98
  fermentation of, 104, 106-110
  as fertilizer, use of, 139-140
    value of, 99-100, 139-140
  harvesting of, 76, 80, 84, 94, 96, 97
  as sizes, 141-143
Seaweed-burning industry, British, 73-79
  French, 79-82
Seed-pearls, mounting, 160
Seekonks, description of, 736
Seines, haul, use of, 243
  number used, 240, 241
  purse, 243-245
  use of, 242-245
Selachii, 200
Shad, canned, statistics, 725
  canning of, 401
  composition, 265-268
  description of, 736
  fins of, 203, 205
  mouth of, 207
Shad fisheries, 233
Shad oil, 440
Shagreen, 494
Shark fins, edible, 412-413
Shark flesh paste, 413
Shark leather, coloring of, 497
Shark-liver oils, 450-453
  problems of, 698
  properties, 451-453
  uses, 453
Sharks, capture of, 494-495
  cub, 497
  description of, 736
Sharks, skinning of, 495
  teeth of, 209
  thresher, fins of, 205
  tiger, 496
  utilization of, 692
Sharks Bay, pearl fishery, 170
Sharkskin leather, 494-498
Sharkskins, tanning of, problems, 699
Sharkskin, tannage, 495-497
Shark stomach leather, 502
Sheepshead, description of, 736
Sheepswool, description of, 736
Shellfish fisheries, distribution of, 228
Shiner, description of, 736
Shrimp, 548-560
  bran, 560
  canned, statistics, 726
  canning, 554-558
  composition, 553
  cooking, 554
  description of, 736
  dried, marketing of, 560
  drying, 558-560
  fisheries, 233
  fishery, 549-553
    haul seine, 549-551
    otter trawl, 549-551
  iced, 553
  marketing of, 553-554
  migrations of, 548
  species, 548
Shrimp meal, 560
Siberia, salted salmon industry, 344
Sicily, tuna canning industry, 398
Silver, in sea water, 24, 27
Silver hake, description of, 736
Silver hake oil, 440
Silversides, description of, 736
Singapore, pearl fisheries, 171
Singapore shells, 171
Sirenians, description of, 736
Skate-liver oil, 447, 454, 455
Skilfish, description of, 736
Skipjack, description of, 736
Skipmackerel, description of, 736
Smelt, description of, 736
  distribution of, 223
Smoke, constituents of, 353
Smoked alewives, 360
Smoked eels, 366-367
Smoked halibut, 365-366
Smoked mackerel, 366
Smoked salmon, 363-365
Smoked sturgeon, 367
Smoke-houses, 348-351
  Chinese, 349
  herring, 350-351
  primitive, 349
Smoking, of fish, problems of, 696
Smolt, description of, 736
Snappers, description of, 736
  distribution of, 223, 224
  red, fishery, methods, 246

Snook, description of, 737
Society Islands, pearl fisheries, 176
Sodium chloride, properties of, 29
Sodium sulphate, recovery of, from bittern, 63, 65, 67
Sod oil, manufacture of, 450
Sole, description of, 736
Sounds, as source of isinglass, 487-488
South Carolina, fishery statistics, 712-715
Spade-fish, teeth of, 209
Spanish mackerel, description of, 737
  mouth of, 207
Spanish mackerel oil, 440
Spawning, seasons of, 218
Spermaceti, 640-642
  composition, 641
  preparation, 640-641
  properties, 641
  refining, 640-641
  uses, 642
Sperm oil, composition, 639-640
  preparation of, 637-639
  properties, 639-640
  refining, 638-639
  uses, 640
Sperm whale, description of, 737
Spikefish, description of, 737
Sponge fishery, history of, 668-669
  hooking, 684
  importance of, 669-670
  machine diving, 684-686
  methods, 683-688
  nude diving, 683-684
  trawling, 686-688
Sponges, 668-690
  bleaching of, 690
  commercial, description of, 672-673, 675-683
    varieties, 675-683
  composition of, 673
  culture of, 673-675
  description of, 737
  economic importance of, 21
  elephant-ear, 682-683
  glove, 678-679
  grading, 689-690
  grass, 678
  hardhead, 679
  honeycomb, 682
  living, characteristics, 670-672
  loading of, 690
  loggerhead, utilization of, 700
  preparation for market, 688-690
  properties of, 672-673
  reef, 679
  sheepswool, 675-676
  Turkey cup, 679-680
  Turkey solid, 679-680
  Turkey toilet, 680-682
  use, 682
  velvet, 677-678
  wire, 679
Sponges, wool, 675-676
  yellow, 676-677
  Zimmocca, 681-682
Spot, description of, 737
  distribution of, 223
Sprat, description of, 737
Sprat oil, 440
Squeteagues, description of, 737
  distribution of, 223-224, 225
  fisheries, 233
  mouth of, 207
  spawning of, 218
Squid, uses of, 622-623, 692
Starfish, description of, 737
Star-gazer, mouth of, 208
Stickleback oil, 440
Stop nets, number used, 240, 241
Storage, of salted fish, 311-314
Striped bass, description of, 737
Striped bass oil, 440
Strombus gigas, fishery for, 158
Sturgeon, description of, 737
  distribution of, 224
  smoking of, 367
Sturgeon-fish, description of, 737
Sturgeon oil, 440
Sulphur-bottom whale, 737
Sunfish, description of, 737
Sunfish oil, 440
Surf-fish, description of, 737
Swell-fish, description of, 737
Swim-bladder, of fishes, 212
Swordfish, description of, 737
  distribution of, 222

T

Tactile organs, 211
Tailor, description of, 738
Tannage, chemical reactions of, 502-503
  chrome, 502-503
  of fur sealskins, 658
  use of cod oil in, 449-450
  vegetable, 502
Tar, use in net preservation, 260
Tarpon, description of, 738
  scales of, 202
Tautog, composition of, 265
  description of, 738
  distribution of, 222
  teeth of, 210
Tautog oil, 440
Teeth, of fishes, 208-210
Teleostomi, 200
Ten-pounder, description of, 738
Terrapin, Carolina, 601
  description of, 738
  diamond-back, 601-606
    capture of, 605
    habits, 602-603
    marketing, 605
  Florida, 601
  propagation of, 602-605

Terrapin, quantity marketed, 597
  Texas, 601
Texas, fishery statistics, 716-719
Therapeutic properties, of cod-liver oil, 448-449
Thimble-eye, description of, 738
Thursday Island, pearl fishery, 170
Tilefish, description of, 218, 738
  distribution of, 223
Tilefish oil, 440
Tomcod, description of, 738
Tongs, oyster, 519, 521
Torre del Greco, coral industry, 196-197
Tortoise shell, economic importance of, 21
  manufacture of, 599-600
Trammel nets, number used, 240, 241
  use of, 252-253
Traps, floating, 251
Trap nets, use of, 248-251
Trawl, bag net, 253-255
  beam, use of, 255
  otter, use of, 253-255
Trawl line, fishery, methods, 246-248
Trepang, smoking of, 368
Trigger fish, teeth of, 209
Triple-tail, description of, 738
Trochus, 174, 176-177
Trochus shells, French imports, 167
Trout, steel-head, mouth of, 207
Trunkfish, body covering of, 203
  description of, 738
Tuna, canned, statistics, 725
  canning, 397-400
    methods of, 399-400
    Sicilian, 397
  capture of, 399
  fishery, methods, 246
  smoking of, 367
  species of, 398
Tuna-liver oil, 454
Tuna scrap, composition, 462
Turbo marmoratus, 173-174
Turbot, description of, 738
Turk's Islands, salt manufacture in, 37-39
Turtle eggs, 598, 601
Turtles, 596-601
  description of, 738
  green, characteristics, 596
    fishery, 597-599
    prices, 597, 598
  hawk'sbill, fishery, 599-600
  Kemp's Gulf, 601
  leathery, 601
  loggerhead, 600-601
  luth, 601
  quantity marketed, 597

U

Uchiwa zame-liver oil, 454
Ulva latissima, use as food in Great Britain, 120
United States, fishery statistics of, 703-726

V

Vacuum cod-liver boiler, 444
Vacuum pan, capacity of, 60
  standard proportions of, 60-61
Vacuum pan salt, 52
Varnishes, manufacture of, from menhaden oil, 430
Venezuela, pearl fisheries of, 155, 170, 177
Vinegar, use on marinated fish, 405
Virginia, fishery statistics, 710-711
Vitamin content, of fishes, 692-693
Vitamins, in cod-liver oil, 277-278, 448-449
  in fish, 276-279
  in herring oil, 277
  in shark-liver oil, 277
  in whale oil, 277
Viviparous fishes, 219
Voice of fishes, 212

W

Walrus, 664-669
  description of, 738
  habits of, 665
  importance of industry, 664-665
  ivory, 666
  location of industry, 664
  methods of hunting, 665-666
  species of, 665
Walrus oil, 666-667
Walrus skins, 494
Wampum, 15
Washington, fishery statistics, 720-722
Weakfish, spotted, fins of, 205
    scales of, 202
Weakfish oil, 440
Weirs, construction of, 249-250
  number used, 240, 241
  sardine, 249-250
West Indies, salt manufacture in, 37-39
Whale, Biscay right, 626
  blue, 627
  bottlenosed, 627
  California gray, 627
  finback, 627
  fish, 627
  Greenland right, 626
  humpback, 626
  Nordkaper, 626
  sei, 627
  southern right, 626
  sperm, 627-628
  white, 628
Whale blubber, 633
Whalebone, 643
Whale bone meal, 642-643
Whale glue, 644

Whale-hide leather, 501-502
Whale meat, 632, 634, 635
  canning of, 634-635
  composition of, 634-635
  nutritive value, 634
  utilization of, 699-700
Whale oil, composition, 637-638
  preparation of, 635-637
  refining of, 635-637
  use of, 637
Whale scrap, composition, 642
  manufacture, 642
  use, 642
Whales, 625-644
  butchering of, 631-632
  capture of, 630-631
  characteristics of, 625-628
  economic importance of, 21
  harpooning, 630-631
  toothed, 627-628
  whalebone, 626-627
Whaletails, pickled, 634
Whaling industry, 628-644
Whaling industry, importance of, 628-630
  location, 628-630
Whelks, 623
White-fish, description of, 738
Whiting, description of, 738
  distribution of, 221
  salting of, 340
Whiting-liver oil, 447, 454
Whiting oil, 440
Window pane, description of, 738
Wolf-fish, description of, 738

Y

Yellowtail, canned, statistics, 725
  canning of, 399
  description of, 738
  salted, 346
Yellowtail oil, 440

Z

Zanzibar shells, 172

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